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Cover.—X-ray of a piece of fir infested with shipworms after 5-month exposure in Ladysmith Harbour, British Columbia. The shells surrounding the head and the pallets can be seen. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.

U.S. DEPARTMENT OF COMMERCE
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MFR PAPER 994

Increasing demand has put heavy pressures on the American lobster supply. Here two economists analyze proposed management measures.

The American Lobster Fishery: Economic Analysis of Alternative Management Strategies

FREDERICK W. BELL and RICHARD F. FULLENBAUM

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The increasing pressure of world demand for fishery products has led to more intensive exploitation of, and, at the same time, to increasing concern over, the marine environment. One recent study predicts that world demand for many species fished by U.S. fishermen will outstrip the maximum world supply potential before 1985 (Bell et al., 1971). Many management strategies used to protect fishery resources from overexploitation have resulted in inefficient use of gear and equipment, as shown by Crutchfield and Pontecorvo (1969). Recently, the National Marine Fisheries Service initiated a State-Federal partnership to develop alternative management strategies so that scarce fishery resources will be used wisely. The purpose of this article is to point out the economic impact of some selected management strategies for the U.S. inshore American lobster fishery. In the course of our analyses, we shall try to describe in simplified terms just how economists go about the task of assessing the economic impact of various management policies. It should be made quite clear that this analysis is intended to predict the effects of alternative actions *without recommending or endorsing any specific policy*. Also, the management strategies tested are not meant to be exhaustive, and there may be others that are worthy of consideration.

THE BIOECONOMIC MODELING PROCESS

Before any specific management strategies are considered, it is first necessary to understand just how a fishery functions from both the economic and biological points of view *without* extensive management intervention by government. This gives us a benchmark from which the economic impact of various management policies can be measured. Economic researchers first attempt to develop a bioeconomic model which will explain the most important behavioral factors for a fishery over some period of time, such as ex-vessel prices, fishing effort, earnings, and catch under conditions of free access to the fishery resource. The "model" consists of a series of mathematical relationships which hopefully approximate the economic behavior of those participating in the fishery. The predictive power of such models is greatly influenced by each of the building blocks, such as the hypothesized relation between catch and effort or catch and ex-vessel prices. The reader should remember that these models only attempt to consider the most important factors for a fishery and necessarily omit factors of lesser importance over the long run.

Although the technicalities of a bioeconomic model will not be discussed here, it should be pointed out that the researcher essentially attempts to explain the determinants of the demand and supply of fish harvested from a given resource.[1] Supply or catch is directly determined by the size of the fishery biomass and the number of vessels fishing the resource. The number of vessels and fishermen fishing the resource is determined by the overall level of consumer demand for the fishery product. Consumer demand is determined by income per capita, population, and ex-vessel prices relative to other protein substitutes. As demand expands over a period of time owing to the expansion of population and/or income, ex-vessel prices will increase, an event which in turn produces an increase in returns to existing vessels and fishermen. The rise in earnings induces more vessels into the fishery, thereby expanding catch given the biological limitation of the resource. The resource limitation is built into the model by relating catch to fishing effort or number of vessels fishing the resource. As fishing effort expands, the catch will eventually reach a maximum yield. Further fishing will reduce catches. Therefore, the concept of maximum sustainable yield (MSY) is the largest number of pounds of fish that can be caught on a long-run an-

[1]For the reader who is interested in a more technical discussion of the bioeconomic model, consult Richard F. Fullenbaum and Frederick W. Bell, "Economic Impact of Alternative Management Strategies for the Northern Lobster Fishery," *Fishery Bulletin* (in press).

nual basis with a given level of fishing effort without impairing the viability of the stock.

The bioeconomic model does permit overfishing the resource where the level of fishing effort is greater than that necessary to harvest MSY. In this case, catch will usually be less while fishermen and vessels will be more than necessary to take MSY. This situation represents a waste of capital and labor. The model will allow us to answer such questions as the following: What is the economic impact of a sudden increase in imports? What will happen to the fleet if the rate of growth of U.S. population slows? What is the impact of increases in per capita income on ex-vessel prices? Let us now turn to some of the basic elements in constructing a bioeconomic model for the American lobster fishery.

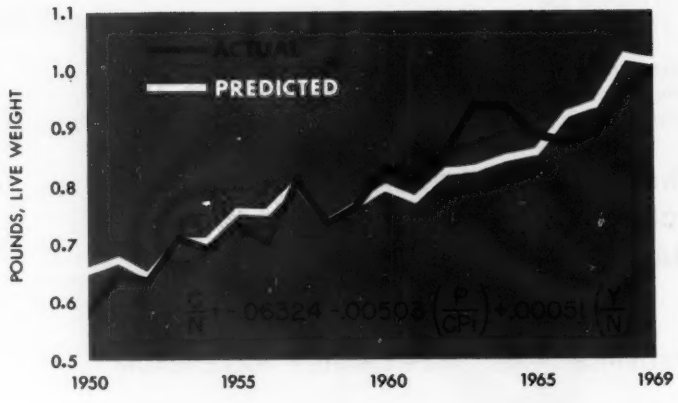

Figure 1.—Actual and predicted per capita consumption of all lobsters, 1950-69. C/N = per capita consumption of all lobsters; P/CPI = real ex-vessel price (or actual ex-vessel price of lobsters) divided by CPI (1967 = 100); and Y/N = real disposable income per capita.

ESSENTIAL BIOECONOMIC RELATIONS FOR THE U.S. AMERICAN LOBSTER FISHERY

A. The Demand for Lobsters

As indicated above, consumer demand for the fishery product is the driving force behind the expansion of a fishery which leads, on occasion, to overfishing. Over the 1950-69 period, U.S. per capita consumption of all lobsters (American, spiny, etc.) increased from 0.585 to 0.999 pounds, live weight (Table 1). The rate of growth in per capita consumption was approximately 2.4 percent per year. This was in sharp contrast to overall U.S. per capita consumption of food fish, which remained relatively constant over the same period at 10 to 11 pounds. The increased consumption came primarily in the imported spiny lobster category. The rapid growth in the consumption of lobsters produced a rise in ex-vessel prices of 4.8 percent per year which exceeded the growth in all consumer prices, which averaged 1.7 percent per year. What were the determinants of the per capita consumption of lobsters? A statistical analysis was made in which the following factors were related to per capita consumption of all lobsters:

1. ex-vessel price of American lobsters relative to the general price level in the U.S. economy; and
2. real per capita disposable personal income (standard of living).

In prior statistical tests, it was found that crab and shrimp prices as well as meat and poultry prices were not significantly related to the per capita consumption of lobsters. It was anticipated that per capita consumption of lobsters would fall if ex-vessel prices increased faster than the general price level and would rise owing to increasing real per capita income. Figure 1 shows the estimating accuracy of our statistical equation, which is consistent with our expectations. This relates the per capita consumption of all kinds of lobsters to ex-vessel prices and per capita income over the 1950-69 period. According to the analysis, a 10 percent increase in lobster prices will reduce per capita consumption by roughly 4 percent. However, a 10 percent increase in per capita income would increase per capita consumption about 15 percent. The consumer demand analysis for lobsters indicated that despite rising lobster prices, per capita consumption increased owing to the rise in the standard of living. This provided strong economic incentive to expand the domestic lobster fisheries.

B. The Supply of American Lobsters

Although the demand for *all* lobsters was considered above, for management purposes we want to focus on one component of the total supply: the inshore U.S. American lobster stock, which is located primarily along the North Atlantic States. The number of traps fished in this fishery expanded from approximately 579,000 in 1950 to 1,061,807 in 1969, an annual rate of growth of 3.6 percent. This largely resulted from the rising demand pressures discussed above. Dow et al. (1961) showed the strong relation between the catch per trap of American lobsters and two important factors: (1) the total number of traps fished, and (2) seawater temperature. That is, catch per trap falls as the total number of traps fished increases. However, within certain ranges, catch per trap is increased by increases in seawater temperature which cause lobsters to grow more rapidly. It should be noted that the

Table 1. — Economic variables associated with the U.S. inshore American lobster fishery, 1950-69.

Year	Catch by traps	Value	Traps fished	Catch per trap	Ex-vessel price	Ex-vessel price divided by consumer price index	Per capita consumption of lobsters	Per capita disposable personal income divided by consumer price index	Consumer price index (1967 = 100)	Mean annual seawater temperature at Boothbay Harbor Maine
	Thousand pounds	*Thousand dollars*	*Number*	*Pounds*	*Cents per pound*	*Cents per pound*	*Pounds (live weight)*	*Dollars*		*Degrees Fahrenheit*
1950	22,914	8,283	578,930	39.6	36.1	50.1	.585	1,892	72.1	49.3
1951	25,749	9,328	512,812	50.2	36.2	46.6	.651	1,888	77.8	51.4
1952	24,681	10,469	544,730	45.3	42.4	53.4	.638	1,909	79.5	50.2
1953	27,509	10,687	569,081	48.3	38.8	48.5	.710	1,976	80.1	52.0
1954	26,628	10,250	628,209	42.4	38.5	47.8	.690	1,969	80.5	50.3
1955	27,886	11,003	669,229	41.7	39.5	49.2	.734	2,077	80.2	50.0
1956	25,386	11,584	666,887	38.1	45.6	56.1	.704	2,141	81.4	48.6
1957	29,358	11,263	688,815	42.6	38.4	45.6	.806	2,136	84.3	48.8
1958	26,143	12,890	753,503	34.7	49.3	56.9	.736	2,114	86.6	47.4
1959	27,752	14,043	856,794	32.4	50.6	58.0	.763	2,182	87.3	47.0
1960	29,345	13,657	844,110	34.8	46.5	52.5	.830	2,185	88.7	47.9
1961	25,621	13,662	895,098	28.6	53.3	59.5	.810	2,214	89.6	47.3
1962	26,728	13,770	909,318	29.4	51.5	56.9	.855	2,280	90.6	46.6
1963	27,210	15,299	866,900	31.4	56.2	61.3	.938	2,333	91.7	47.9
1964	26,844	17,689	904,233	29.7	65.9	70.9	.935	2,459	92.9	46.9
1965	24,737	18,764	949,045	26.1	75.9	80.3	.884	2,578	94.5	45.8
1966	25,606	19,517	947,113	27.0	76.2	78.4	.873	2,680	97.2	45.7
1967	22,098	18,162	907,956	24.3	82.2	82.2	.882	2,751	100.0	45.1
1968	26,918	20,648	966,335	27.9	76.7	73.6	.960	2,827	104.2	46.6
1969	26,930	22,997	1,061,807	25.4	85.4	77.8	.999	2,851	109.8	48.0

Sources: *Fishery Statistics of the United States*, various years, U.S. Department of Commerce, Bureau of Labor Statistics, and Robert Dow.

traps fished series is not an exact measure of fishing effort since it is not adjusted for days fished or extent of utilization. However, this series can serve as a rough proxy because, in general, when traps increase, trap days increase also. For the 1950-69 period, Figure 2 shows the estimating accuracy of our statistical equation which relates catch per trap to the total number of traps fished and seawater temperature. Over the 1950-69 period the catch per trap decreased because of a rise in traps fished and a fall in seawater temperature. For the 1969 level of seawater temperature (i.e., 48° F), the estimated maximum sustainable production or yield of the inshore American lobsters from the resource was approximately 28.7 million pounds (live weight). This would have required approximately 1.011 million lobster traps to catch. It would appear that the inshore American lobster fishery has sufficient traps to catch MSY and, therefore, is fully capitalized.[2] This "estimate" agrees fairly well with 31 million pounds indicated in the Master Plan Essay (U.S. Department of the Interior, 1970). Based upon this analysis, there is every indication that the inshore American lobster resource is fully exploited.

The only other critical variable needed in our bioeconomic model is the opportunity cost, or returns necessary to make it profitable for vessels and fishermen to fish for lobsters. An updated sample of cost and earnings for lobster boats indicated that a fulltime boat *must* have earned approximately $13,191 per year in 1969 in order to cover fixed and operating expenses and have an adequate return to both capital and labor to make it profitable for them to stay in the industry or fishery. This dollar estimate of opportunity cost is admittedly quite crude, and the National Marine Fisheries Service is presently working on better estimates through a contract with the University of Maine.

[2]The word "capitalized" is a shorthand expression that represents inputs of vessels, fishermen, gear, and technology which are employed to harvest a fishery resource. In the case of inshore American lobsters, there is enough gear (i.e., traps), boats, and fishermen to harvest MSY; therefore, the fishery is fully capitalized.

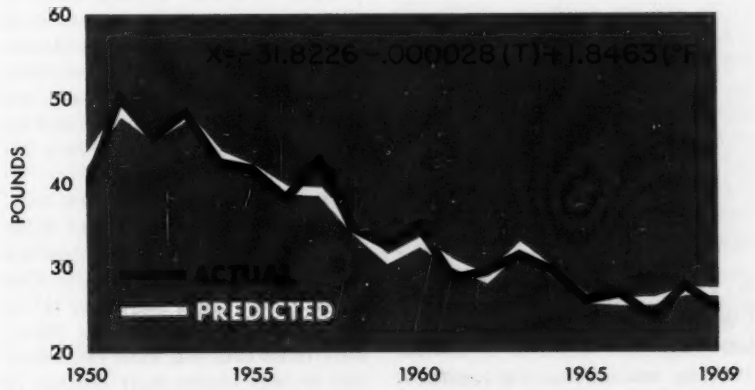

Figure 2.—Actual and predicted catch per trap of all inshore American lobsters, 1950-69. X = catch per trap; T = number of traps; °F = mean annual seawater temperature.

ECONOMIC IMPACT OF SELECTED MANAGEMENT ALTERNATIVES

Up to this point, we have been concerned largely with building a bioeconomic model that considers all the important variables. The model is based upon the fact that open access to the American lobster fishery is permitted. All states restrict gear to pots and traps. Each state (Maine, Massachusetts, New Hampshire, and Rhode Island) has a minimum lobster length requirement; permitted minimum lengths vary from $3\frac{1}{16}$ to $3\frac{3}{16}$ inches. Although there are various other restrictive regulations, e.g., prohibitions on catching egg-bearing females, their effect on the fishery is nominal and certainly less important than the size limitations. *We are, however, taking the array of existing regulations as given.*

We shall consider the economic impact of five alternative policies that could be adopted to manage the entire inshore American lobster fishery. These management strategies assume that some central authority such as a regional commission could impose these regulations. Further, the following strategies are meant to be illustrative and do not exhaust all possible alternatives. Also, two other management strategies suggested by Reeves (MS.) and Sinclair (1961) will be reviewed. As other management strategies are suggested by industry, government, and the academic community, the model formulated above may be used to predict their impact. The specific objectives of these management strategies will be discussed below. All strategies have two common objectives: (1) to protect the resource from overexploitation and (2) to allow maximum freedom for operators to function in a free enterprise fashion.

A. Freeze on Existing (1969) Fishing Effort by Placing a License Fee on Traps

Under this scheme, the regulatory authority would calculate a license fee on traps (approximately 1.069 million in 1969) which would keep the level of fishing effort constant despite an increase in the demand for lobsters. A license fee could not be levied on the individual vessel because this would not control the number of traps fished per vessel. The increased cost of operations due to the license fee would make it uneconomical for vessels to enter the fishery even if ex-vessel prices had increased. In essence, the license fee would siphon off increased revenue (or profits) from an increase in ex-vessel prices, assuming the latter increase faster than the cost of operations. For purposes of illustration, let us assume that we desire to manage the inshore American lobster fishery commencing in 1974. Given the trends in U.S. population, personal income, consumer prices, lobster imports, and other domestic production to the year 1974, it would be necessary to place an estimated annual license fee of $3.34 on each lobster trap fished. The regulatory authority would collect over $3.56 million which could be used to finance resource research, enforcement, and surveillance.

The bioeconomic model discussed above was used to estimate the necessary license fee. It should be emphasized that these calculations are merely rough estimates and only serve to give the reader some idea of the magnitude of such taxation. The illustrative license fee is also based upon an extrapolation of trends 5 years ahead of 1969. If we did nothing, it is estimated that the catch would be lower and more fishermen and traps would be employed in the fishery by 1974. Obviously, the situation would worsen as demand for lobsters expanded and the fishery became increasingly overfished.

The licensing fee plan does, however, have many disadvantages. First, a license fee on traps fished does not really get at the utilization rate. One might expect that a license fee on an individual trap might induce fishermen to fish each trap more intensively and thereby reduce their number of traps. At this point, we do not have any information or utilization rates whereby the license fee could be adjusted upward if utilization increased. Second, enforcement and surveillance might be difficult along the coastline from Maine to North Carolina. Third, and most important, the quantitative tools and projected figures needed to calculate a license fee are at best crude and would have to be used each year for computation of the license fee.

B. Reduce the Existing Level of Fishing Effort to that Necessary to Harvest MSY by Placing a License Fee on Traps

With this scheme, the regulatory authority would calculate a license fee on traps which would reduce the level of existing effort to that necessary to harvest MSY (estimated to be about 1.011 million traps) despite an increase in demand for lobsters. Because we are actually reducing fishing effort as opposed to freezing it at the 1969 level, the estimated 1974 license fee per trap must be higher, or $5.54; actual catch will not be significantly higher. The regulatory authority would receive approximately $5.58 million in license fee revenue. However, this plan has all the disadvantages of a general license fee plan discussed under an alternative one.

C. Reduce the Existing Level of Fishing Effort to that Necessary to Make the Marginal Cost of Landing Equal to Ex-Vessel Price by Placing a License Fee on Traps[3]

The idea here is to obtain the greatest "net economic benefit" and was

[3]For most industries, output will expand in reponse to demand up to the point where the marginal cost of production (i.e., additional cost of producing one more unit of output) is equal to the price received in the marketplace. This is considered an efficient level of production. In the fishing industry, the condition does not hold because of the common property nature of the resource coupled with resource limitations. Marginal cost pricing is never achieved in fishing, and it is argued by some economists that regulations should be so structured to achieve this objective.

suggested by such economists as Crutchfield and Pontecorvo (1969). If a regulatory authority had tried this for the year 1971, it would have had a drastic impact on the fishery as the number of full-time equivalent vessels and traps would have been reduced by approximately 40 percent. To accomplish this objective, an estimated 1974 license fee of $22.43 per trap would be needed. This would yield the regulatory authority approximately $13.3 million in revenue.

From an economic point of view, it is argued that this management strategy will result in the most efficient operation of the fishery if fishermen and vessels can easily move to other fisheries or industries. However, this strategy may be particularly unwise in rural areas such as Maine where labor mobility is low. A drastic cutback in the number of fishermen may increase social problems where the cost would greatly exceed any benefits derived from such a management strategy. Therefore, this management strategy is difficult, if not impossible, to justify on economic grounds for many rural areas where the fishing industry is located and also has the same disadvantages as a general license fee plan on traps as discussed above.

D. Issue "Stock Certificates" to Each Vessel Owner Based on Average Catch over the Last Five Years while Freezing the Existing Level of Fishing Effort

Under this scheme, the historic rights of each fishing firm would be recognized. In a manner similar to a private land grant procedure, the regulatory authority would simply grant each fisherman a "private" share of an existing resource or catch. The stock certificate would be evidence of private ownership. Individual fishermen would be free to catch up to their allotted share through the use of pots or other biologically permissible technology; or, if they desired, trade their stock certificates to others for cash.

Suppose the regulatory authority were to freeze the level of fishing effort at the 1969 level and distribute the catch via a stock certificate to the existing fishermen. It should be pointed out that the regulatory authority fixes effort when it selects a given catch. The selected catch could be either MSY or any other level of catch deemed by the regulatory authority not injurious to the viability of the stock. The expansion in demand for lobsters by 1974 would generate excess profits for those individual fishermen who were initially endowed with the property right. By 1974, it is estimated that a full-time lobsterman would be earning $10,278 a year of which $1,878 would be excess profits (i.e., above opportunity cost). If profits become excessive, a license fee could be levied on the fishermen holding stock certificates to insure against increasing abnormal returns and providing the regulatory authority with funding to conduct scientific investigations and enforcement.

It should be noted that this plan is identical to the licensing scheme which freezes effort at the 1969 level. However, in the latter case excess profits are taken by the regulatory authority, while for this strategy fishermen are allowed to hold onto the profits generated in the fishery. Since many fisheries are located in rural areas where earnings are traditionally low, this strategy might be justified on the basis that it will raise income levels and thereby help improve living standards to levels comparable to those received in urban areas. This management strategy would, of course, be popular with those already in the fishery. However, new entrants would have to buy stock certificates from those initially in the fishery. This would pose certain questions of equity and legal precedent which are beyond the scope of this article.

E. No Management Strategy

When considering the economic consequences of alternative management strategies (A through D), it is always wise to assess the results of doing nothing. This gives policymakers a better perspective in evaluating the benefits from taking action.

The consequence of doing nothing would be overcapitalization by 1974 with an expansion in the number of full-time equivalent fishermen and traps fished. Over 96,000 excess traps would be in the fishery, and the catch would fall to 28.1 million pounds. The fishery would grow increasingly overcapitalized and the resource greatly overexploited as demand increased for lobsters during the 1970's. On economic grounds, these results are hardly acceptable because more fishermen and vessels will be catching less.

F. Other Suggested Management Strategies

Reeves (MS.) proposed a hike in license fees to "eliminate" marginal or part-time fishermen. He suggested that the present $10 yearly fee in Maine be raised $10 a year over the next 9 years to a limit of $100. In 1969, a little less than one-half of the lobster fishermen were part-time. As defined by Reeves, a part-time lobster fisherman is one who gains less than one-half of his annual income from lobstering.

The first step in most suggested limited entry schemes is usually to restrict the fishery to full-time utilization of capital and labor. Two problems occur with this policy. First, the part-time fishermen may represent the most efficient way of taking the catch. If so, the full-time fishermen may be eliminated by increased license fees. Second, license fees do not directly control fishing effort since fishermen may fish more traps. However, Reeves went on to argue strongly for limiting the number of traps each fisherman is allowed to set. It is not quite clear whether anyone knows the optimum number of traps per vessel.

Rutherford, Wilder, and Frick

(1967) in their study of the Canadian inshore lobster fishery endorsed the system suggested by Sinclair (1961). They stated:

> An alternative management system is that suggested by Sinclair (1961) for the salmon fisheries of the Pacific coast. This would use the licensing of fishermen to limit entry into the fishery. In the first stage, lasting about 5 years, licenses would be reissued at a fee but no new entries would be licensed and it would be hoped that during the period there would take place a reduction in the labor and capital input, to take the maximum sustainable catch of salmon at a considerably lower cost. After the end of the first stage, licenses would be issued by the government under competitive bidding and only in sufficient numbers to approximate the most efficient scale of effort; the more competent fishermen would be able to offer the highest bids and it would be expected that the auction would recapture for the public purse a large portion of the rent from the fisheries that would otherwise accrue to the fishing enterprises under the more efficient production conditions in the fishery.
>
> An arbitrary reduction in the number of fishermen by restriction of licenses to a specified number would entail injustice and inequity as well as grave administrative problems in determining who should be allowed to continue fishing. The auctioning of licenses to exploit a public property resource is justifiable in a private enterprise system of production, particularly when the state is incurring heavy expense to administer and conserve the resource; the recovery by the state of some part of the net economic yield by means of a license fee on fishermen (or on the catch) would recoup at least part of such public expenditures, or could be used to assist former fishermen [see strategies discussed above], for instance, by buying their redundant equipment. A license fee on fishermen through the auctioning of licenses has, at least, the merit of using economic means instead of arbitrary regulations to achieve a desired economic objective—the limitation of fishing effort to increase the net economic yield from the fishery. Regulations have to be enforced, usually at considerable cost, but economic sanctions tend to be, if not impartial, at least impersonal and automatic in their operation. (pp. 99-100)

Actually, this latter management scheme is similar to the licensing scheme, but uses an auction rather than a direct license fee.

CONCLUSIONS

The purpose of this article was to explain the use of bioeconomic models in assessing alternative management strategies. For this purpose the data were less than optimal. However, this does not mean that we cannot take steps in the direction of fishery management. In fact, these steps must be taken to protect the resource from destruction and to achieve a better use of vessels and fishermen. It is hoped that the following conclusions will provide a helpful framework in which to consider the merits of limited entry.

A. For the inshore American lobster resource we see every indication that the fishery has achieved MSY and is fully capitalized. This has been brought about by a rapid expansion in effort (i.e., traps fished) produced by (1) free access to the resource, (2) a rising market for lobsters of all species, and (3) a secular decline in seawater temperature.

B. We have presented the bioeconomic impact of alternative management strategies to both conserve and use the resource efficiently. The choice of which strategy to pursue is in the public domain and beyond the scope of this paper. However, the economic alternatives have been pointed out.

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MFR PAPER 995

Millions are spent annually combating the ravages of tiny marine creatures that attack underwater structures.

Shipworms and Other Marine Borers

MICHAEL CASTAGNA

INTRODUCTION

As long as man has launched wooden boats or built wooden structures in the sea, he has suffered from the activities of shipworms and other marine boring animals. Wherever a wharf or piling stands in salt water these seldom-seen enemies are ready to attack. Records show that as far back as 412 B.C. arsenic and sulfur mixed with oil was used on wooden structures to prevent shipworm invasion. During Columbus's time, bottoms of ships were covered with a mixture of tallow and pitch in hope of discouraging shipworms and various fouling organisms. It is possible that the crew sailing with Columbus wanted to turn back not in fear of the unknown but rather that they might not return to land before the shipworms sank their vessels. In the reign of Henry VI (1421-1471), a ship sent on a voyage of discovery records the use of lead sheathing around the keel to keep out worms "which many times pearseth and eateth through the strongest oak that is."

The unfortunate introduction of the European shipworm in San Francisco Bay about the year 1913 resulted in unprecedented destruction of exposed wooden structures. In the period of a few years following their introduction at least $25 million damage was attributed to these "termites" of the sea.

Today, large sums of money are spent annually for the control of these animals. Even so, periodic replacement of submerged structures is still necessary.

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MOLLUSKS

Shipworms

The most destructive of the marine wood borers is shipworm or teredo. This mollusk enters submerged timbers when it is very small and grows rapidly inside the wood. Myriads of these creatures riddle the interior of the wood until, without noticeable damage on the outside, an entire structure may suddenly collapse.

Classification

Shipworms are mollusks belonging to the class Pelecypoda which includes such bivalves as clams, oysters, and mussels. They are members of the family Teredinidae in the order Teleodesmacea. *Teredo* and *Bankia* are the two common genera found along the coasts of the United States.

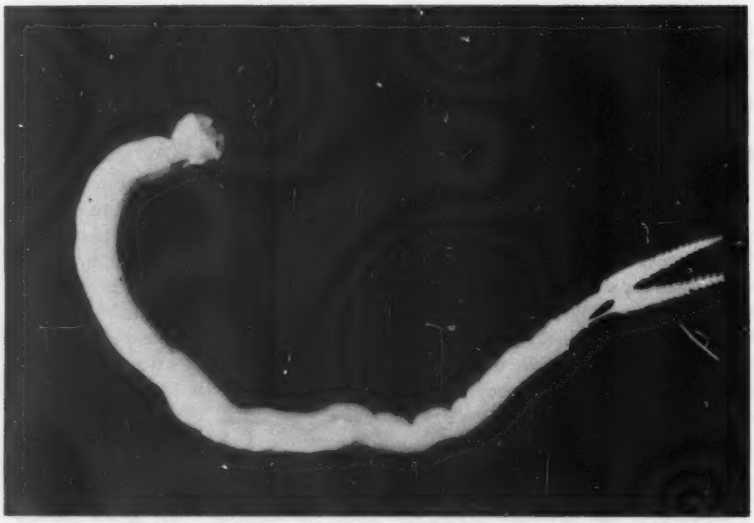
Description

The shipworm is unusual in its relation to its habitat. Few instances can be cited wherein marine organisms are dependent upon organic products from the land, as is the rule with this mollusc-can wood borer. Parts of its body have become greatly modified in adaptation to its peculiar mode of life and, though the shipworm is a bivalve mollusk, it differs greatly in appearance from such familiar bivalves as clams and oysters.

It has an elongated, naked, worm-like body. This superficial resemblance to worms misled early investigators, who failed to recognize it as a mollusk. The two valves of the shell are reduced to a pair of small, curved plates that lie alongside the head where they serve as boring tools. The edges of these reduced shells are equipped with rows of fine teeth which make them efficient rasping organs. The soft body, though greatly extended, is fundamentally the same as that of typical bivalve mollusks.

An average adult shipworm measures 4 to 6 inches long and less than ¼-inch in diameter, but some species grow to considerable size. An Australian species, *Dicyathifer*, sometimes exceeds 1 inch in diameter and 6 feet

Shipworm, genus *Teredo*, being drawn from a test block. Photograph by Robert F. Sisson, courtesy, National Geographic Society.



Above is the shipworm (*Bankia setacea*). Whole animal removed from the burrow. The feather-like structures at the right are the pallets. The two shells are at the left end. Magnification X2/3. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.

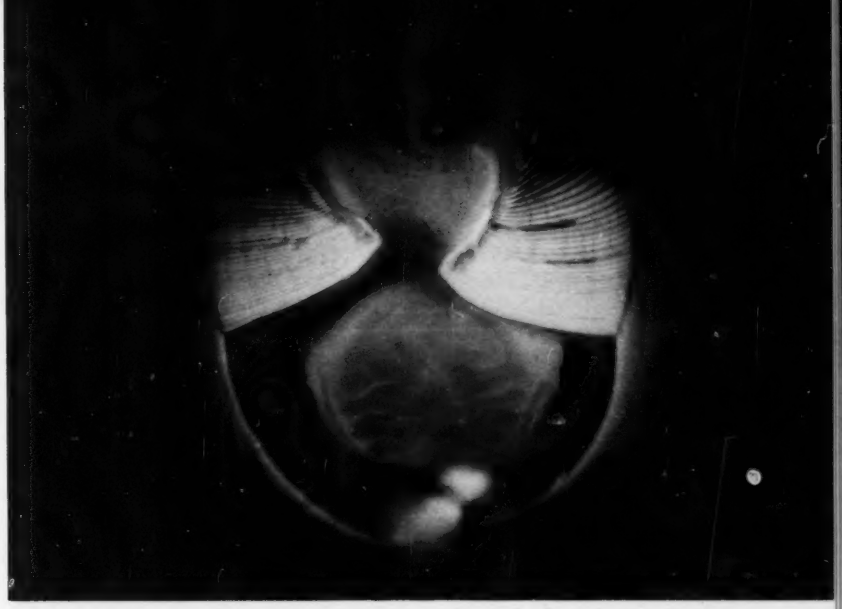
in length. This shipworm is often used for food by the Australian aborigines. The natives of Tierra del Fuego also consider one of the larger species of shipworm an excellent sea food and even anchor logs in infested areas where they can be recovered and the mollusks harvested.

A pair of tube-like structures is located at the rear end of the body. These are the incurrent and excurrent siphons which are used in feeding and respiration. When the animal is normally extended, the siphons protrude through the opening of the burrow into the water. By the movement of numerous small hairlike cilia which line the body canal, water is continuously swept into the incurrent siphon, through the gills, and out the excurrent siphon. The sea water contains minute plant and animal organisms known as plankton. These organisms, most of which are microscopic in size, are the food of the shipworm. They are strained from the water circulating through the body canal and passed into the gullet by means of the gills. Dissolved oxygen in the water is taken up by the blood as it passes through the gill. The current of water also keeps the body moist and carries away waste materials, which are discharged through the excurrent siphon.

A large quantity of fine sawdust, produced by the shells rasping against the wood, is swept into the digestive tract. There is some controversy as to whether shipworms drill into timber for food. Considerable evidence is available to indicate that, like other bivalves, they bore into such material mainly for its support and protection. However, shipworms do contain in their liver an enzyme capable of producing a simple sugar from some parts of the wood. This suggests that wood may be used as a source of nourishment to some extent. In most cases, however, the wood particles are expelled unchanged in composition. Members of this family have been found boring into asphalt, bakelite, concrete, limestone, rubber, Micarta, paraffin, neoprene, manila, sisal, and a

considerable number of plastics, none of which can be considered as a nutrient material.

At the rear end of the body, near the siphons, is a hard, calcareous, paired structure known as the pallet. The pallet is an organ peculiar to the shipworm and varies in size and shape in the different species. If for any reason conditions outside the burrow become unfavorable, the siphons are drawn into the burrow and the pallet is thrust into the opening to serve as a plug. Enough water is retained in the burrow in this way to keep the body moist until the siphons are again extended and a normal water current reestablished.



Above is a front view of head of a shipworm showing foot with shells on each side. Magnification X7. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.

Reproduction and Early Life History

Some species of shipworm are hermaphroditic, alternately producing sperm or eggs, but in other species the sexes are separate. Eggs and sperm are discharged through the excurrent siphon, and fertilization usually takes place while they are floating free in the water. Water temperature controls the general period of the breeding season and initiation of spawning. In some species, including *Teredo navalis*, the eggs are retained in the gill chamber of the female where they are fertilized by sperm drawn in with the entering current of water. In other species, the eggs develop into larvae inside the burrow of the female. A female shipworm may discharge as many as 100 million eggs; thus infestation can spread quickly if unprotected wood is available.

Upon development the fertilized egg of the shipworm becomes a free-swimming larva. It soon develops a bivalve shell into which the entire body can be withdrawn. Like other bivalves it has a velum, a paddle-shaped swimming organ covered with beating hairs called cilia, by which it propels itself about during its free-swimming existence. It also develops a relatively large muscular foot that enables it to crawl over submerged objects. After 1 or 2 weeks the larva is ready to transform into its adult form and ceases its purely planktonic life. It begins to crawl about until it finds a suitable notch or crevice in a submerged wooden structure. It then secretes a thread-like byssus by which it attaches itself to the surface of the wood. This is the beginning of its sedentary existence. The shell transforms into the rasping organ previously described, the foot develops into a pestle-shaped organ which assists the shell with its boring, and the swimming organ is absorbed.

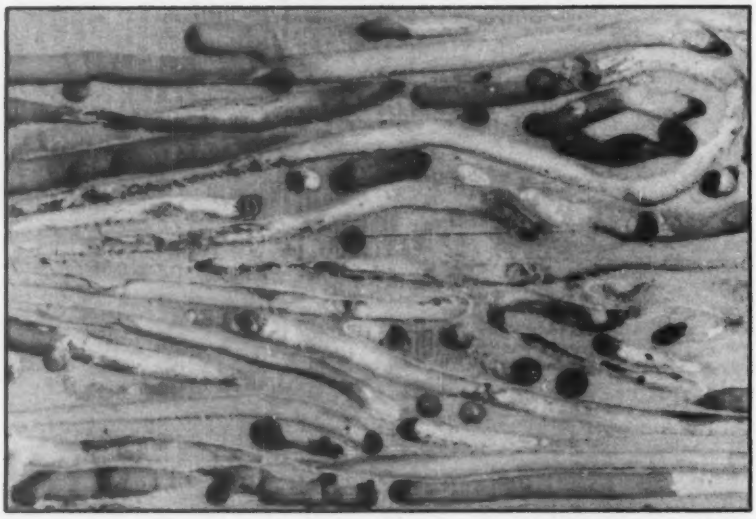
The young shipworm then bores a tiny hole just large enough to admit its body and begins to burrow and grow. As the tunnel is deepened, it is enlarged to about ¼-inch in diameter to accommodate the growing animal. The body elongates and completely fills the burrow but the entrance hole is never enlarged. The walls of the burrows are lined with a thin layer of calcareous material which is secreted by the mantle tissue of the animal. As the shipworm tunnels, it becomes completely dependent on its burrow and cannot live if removed. Should the burrow be punctured, respiration ceases and the animal dies. The burrows never connect or break through to the outside and external contact with the sea water is maintained only by the extended siphons.

Distribution

Adult shipworms are spread as the wood they occupy is carried by water currents as well as by movements of wooden-hulled vessels. Probably because of this they have almost worldwide distribution. All infestations of shipworms were once believed to be caused by one species, *Teredo navalis*. Although *Teredo navalis* does have a wide distribution, it is now known that there are a great many species of shipworm that occur in different parts of the world. Each species has its definite geographical range to which it is restricted by such factors as water salinity and temperature.

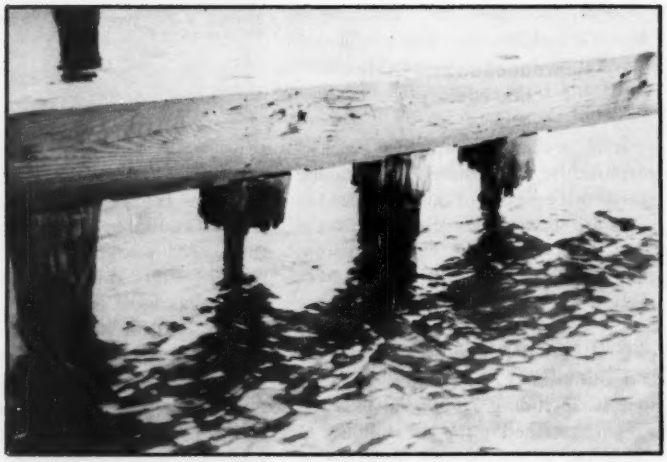
Damage by Shipworms

The annual destruction of submerged wooden structures by shipworms is enormous. The U.S. Navy has estimated that damage to boats, barges, bulkheads, docks, piles, and bridges in the United States exceeds $50 million annually. This damage is especially



(Left.) A piece of fir showing the complete destruction of timber caused by the shipworm *Bankia setacea*. Burrows show calcareous lining secreted by the animal. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.

(Right.) Piling ravaged by gribbles. Unlike the shipworm, this easily spotted marine borer attacks the surface of wood, destroying it layer by layer. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.



(Left.) Section of wooden structure riddled by shipworms. Photograph by Dr. D. B. Quayle, Fisheries Research Board of Canada.

dangerous since the animals enter the wood as minute individuals leaving a very small entrance hole. Because this hole is never enlarged, a thoroughly honeycombed piece of timber may look sound externally. Thus shipworms are not easily detected, and their infestations can be treacherous and costly.

Boring Clams

Clams of the family Pholadidae are another important group of boring marine animals.

Description and Natural History

These are bivalve mollusks closely related to the shipworms. Unlike the shipworms, the boring clams are not wormlike in appearance but have retained the typical bivalve form with the body usually enclosed in two shells. *Martesia*, the wood piddock, is the best known member of this family and one of the most destructive species which attack wood. It has been known to attack creosoted timbers, concrete, and even the lead sheathing of underwater cable. The boring clams are ¾ to 1 inch in length and have brittle, white to dark grayish shells which gape at both ends. These clams are usually elongated and narrow and somewhat wedge-shaped toward the rear end. The front end of the shell is armed with rough, abrading ridges. Some species have additional shelly plates reinforcing the hinge or the margin of the shell. Boring is accomplished by a rocking and heaving motion of the shell, produced by a strong adductor muscle. The boring clams penetrate an inch or more into the wood, usually working toward the grain.

Distribution

These animals live in sea water of full salinity or only slightly brackish water. They have an almost worldwide distribution but are not as common as shipworms. Three species of *Martesia* are found along almost all our shores.

There are a number of other marine bivalves that are capable of burrowing into submerged rock, concrete, or stone, sometimes causing damage to structures built of these materials. The most important species belong to the genera *Pholadidea*, *Zirfaea*, *Petricola*, *Platycodon*, *Saxicava*, *Carditramera*, and *Lithophaga*.

CRUSTACEANS

Types and Descriptions

Three genera of the class Crustacea include some important marine boring animals: *Limnoria*, *Sphaeroma*, and *Chelura*. These are often collectively called gribbles. The most important of these is *Limnoria*, an animal ⅛- to ¼-inch in length somewhat resembling a wood louse. One species, *L. lignorum*, a member of the order Isopoda, is found along our shores. It has a cylindrical, slipper-shaped body divided into segments and capable of rolling into a ball. It has a small head and a broad tail-plate, used to seal off its burrow. There are seven pairs of jointed legs, each terminating with a sharp, curved claw. Five pairs of legs, each having two wide plates which act as gills, are located under the posterior part of the body. These gill-plates are also used as paddles for swimming. The horny jaws are modified for boring; the right jaw has a sharp point with a roughened edge which fits into a groove, and the left jaw has a rasplike surface. Together, they form an efficient rasp and file combination. The burrow is about one-twentieth of an inch in diameter and runs at a slight angle under the surface of the wood. The burrows interlace, generally following the softer spring wood between harder layers of autumn growth.

This animal is especially dangerous because it can attack creosoted as well as untreated timbers. The damage is not as extensive as the burrowing of shipworms, for instead of boring deeply into the wood the gribble excavates galleries just under the surface. As the underlying wood becomes honeycombed, the surface layer is usually worn away by water currents, exposing the damage and giving ample warning of the need for repairs. As the burrows are exposed, the animals tunnel into the next layer of wood.

Limnoria migrate short distances from one wooden structure to another, and the new location then becomes a breeding site. The females are fertilized directly by a male and carry their eggs beneath the abdomen. Breeding occurs at least once a year and females produce from 6 to 17 young in each brood. The young, when hatched, look like miniature adults and bore at once into the wood. Since they start their burrow near the parents', infestation spreads slowly from a center.

Sphaeroma, also an isopod, is much the same in appearance and habits except it is larger, usually about ½-inch in length. The body is oval, convex, and also capable of rolling into a ball. The burrows of this borer are substantially larger than those of *Limnoria*, sometimes exceeding ½-inch in diameter.

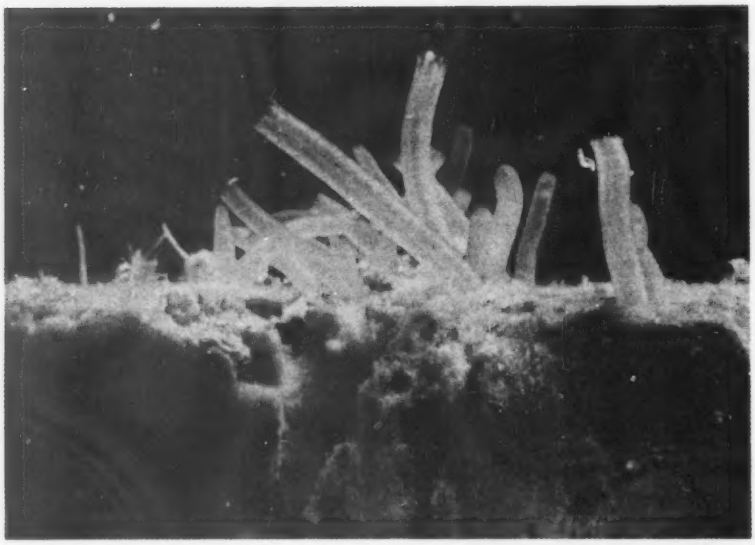
Chelura is another boring crustacean but, unlike *Limnoria* and *Sphaeroma*, it is in the order Amphipoda. Its body is cylindrical and shrimplike, about ¼-inch in length. It can be distinguished from *Limnoria* and *Sphaeroma* by its longer antennae and tail appendages. Its habits are similar to those of *Limnoria*, but its burrows are somewhat larger.

Distribution

These crustacean borers are found throughout the world. *Limnoria* have an especially wide distribution and are plentiful in northern harbors as well as in the tropics.

OTHER GROUPS

Other groups of invertebrate animals including polychaete worms, sponges, and bryozoans are also considered to be marine borers. Although these organisms do penetrate into the outer layer of submerged wood, the damage



Teredo siphons extended out of entrance holes in infested timber. When disturbed the shipworm pulls in siphons and blocks the entrance with twin calcareous plugs. Photograph by Robert F. Sisson, courtesy, National Geographic Society.

they do is only superficial. It is very unlikely that these animals alone could cause damage to submerged structures. They are often present on gribble-infested timbers and thus share some of the blame for any damage.

CONTROL AND PREVENTION

Shipworms and marine borers have few natural enemies. Principal among them are carnivorous worms which prey on shipworms, and many species of small fish which attack exposed gribbles. However, these animals do very little to keep shipworms and borers in check. Environmental factors are the main restriction on their activities. Low water temperatures and salinities can cause them to become dormant and water currents over 1½ knots can prevent larval shipworms from becoming attached. Pollution, especially industrial effluents, is a deterent to shipworms, and almost immediate invasion takes place in areas when such conditions are corrected. Dense distributions of plankton organisms, fouling organisms, or even organic material in the water can also inhibit the setting of shipworm larvae.

The most effective control of shipworms and other marine borers is by chemical treatment of submerged wooden structures. Today, protection of submerged structures is essentially an engineering and chemical problem. Thousands of dollars are spent annually in testing and developing new protective processes. In general, wooden materials can be protected by impregnating the wood with some substance that is repellent to boring animals; or by covering the surface with metal sheathing, concrete, or a hard coating, such as fiber glass; or by painting with a repellent or poisonous paint. Creosote mixtures are the most widely used for impregnation. Although they do not give absolute protection, they prolong the life of wooden structures by many years. The effectiveness of this type of treatment is dependent upon the kind of wood, method of impregnation, composition of the creosote material, and the locality. Metal sheathings are effective but need frequent replacement as a result of the corrosive action of sea water. Concrete sheathing is also affected by sea water. Hard coatings, such as fiber glass, seem to be effective and long lasting. Many antifouling paints have been developed which contain a variety of materials toxic to shipworms. Probably the most commonly used active ingredient is copper or a copper compound. Of course, paint requires periodic renewal—making it useful only on floating equipment or structures which can be hauled out for repainting.

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MFR PAPER 996

The monofilament gill net is more efficient than multifilament and a good sampling tool in high-seas salmon investigations.

Comparison of Salmon Catches In Mono- and Multifilament Gill Nets

PERCY WASHINGTON

ABSTRACT

Mono- and multifilament gill nets of the same mesh sizes were comparatively fished from the RV George B. Kelez *for Pacific salmon,* Oncorhynchus *spp., and steelhead trout,* Salmo gairdneri, *in the Gulf of Alaska and North Pacific Ocean during the winter, spring, and summer of 1971. Catches were analyzed by catch per unit of effort (CPUE), species composition, and length composition of the fish. Relative efficiencies of mono- and multifilament gill nets varied considerably by season, species, and mesh size, but monofilament gill nets were generally more efficient with the CPUE 2.2 times that of multifilament nets. The species composition of salmon catches in mono- and multifilament gill nets in spring and summer were different owing to a higher percentage in multifilament nets of chum salmon,* O. keta, *in spring and of chum and coho salmon,* O. kisutch, *in summer. Means and/or variances of length were, in general, statistically different; monofilament-caught fish were generally slightly larger.*

INTRODUCTION

Since 1955, the National Marine Fisheries Service (NMFS), formerly the Bureau of Commercial Fisheries, has conducted 50 research cruises to the North Pacific Ocean and Bering Sea to study the ocean distribution of Pacific salmon, *Oncorhynchus* spp. Studies covered all seasons to 1971. Multifilament gill nets were the primary gear used; before 1960 this was the only type of synthetic fiber gill net available. Although Larkins (1963, 1964) found monofilament nets to be more efficient, multifilament gill nets are still used on research vessels because of their lower cost, easier handling, and storage qualities (Figure 1).

New types of monofilament materials with much improved handling qualities have been developed since Larkins' experiments. The widespread and productive use of these new monofilament gill nets by the Japanese mothership fleet fishing for salmon stimulated interest in a re-evaluation of the comparative merits of the two fiber types. Tests were, therefore, conducted in 1971 to determine if the monofilament nets were more efficient for sampling populations of salmon at sea than multifilament nets.

Mono- and multifilament gill nets of the same stretched mesh size were fished simultaneously and tested for differences in catch per unit of effort (CPUE), species composition, and length composition.

Percy Washington is a scientist on the staff of the NMFS Northwest Fisheries Center, Seattle.

METHODS AND MATERIALS

Comparative catches of salmon in mono- and multifilament gill nets were obtained in 13 sets in winter, 15 sets in spring, and 21 sets in summer, 1971.

Description of Gear and Equipment

An experimental design was formulated to fish on a test and comparative basis, four mesh sizes (3¼-, 3⅞-, 4½-, and 5¼-inch) of mono- and multifilament gillnets during the 1971 cruises. Mono- and multifilament gillnet strings used during the three cruises were as shown in Figure 2. Both types of nets were fished as one string with no gaps between nets; the monofilament nets were fished closest to the vessel.

The monofilament gillnets were of two types, three different fiber diameters, and two colors. The 3¼-, 3⅞-, and 4½-inch nets were purchased in 1970 from the Momoi Fishing Net Mfg. Co., Japan[1], whereas the 5¼-inch nets were purchased in 1964 from the Miye Seimo Co. Ltd., Japan. The former three nets had heat-set double knots and were light blue, whereas the latter (5¼-inch) had heat-set single knots and were dark brown. Stretched mesh sizes and fiber diameters were: 3¼-inch (0.40 mm); 3⅞-inch (0.50 mm); 4½-inch (0.50 mm); and 5¼-inch (0.60 mm). The more recently manufactured netting tended not only to be much more flexible and resilient but possessed stretch qualities greater than can be attributed to diameter size alone.

The main gill net string of multifilament nets used in 1971 varied in

[1]Use of trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service, NOAA.

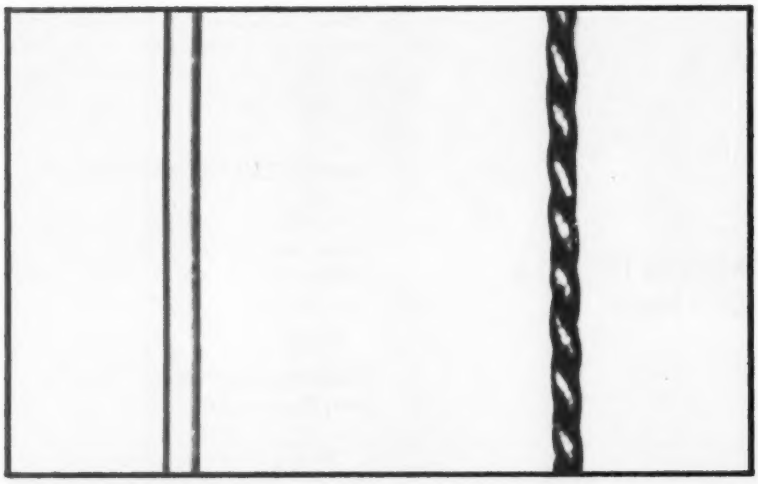

Figure 1.—North Pacific Salmon fishing tests showed monofilament gillnets (left) to be more efficient than multifilament (right). Multifilament gillnets are still widely used owing to their lower cost, ease of handling, and storage qualities.

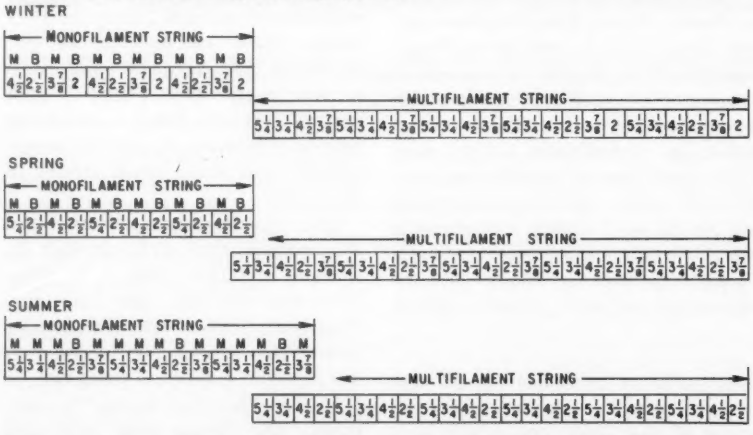

Figure 2.—Diagram of mesh size arrangement of monofilament (M) test and main multifilament nets as fished during winter, spring and summer 1971. Braided or multifilament nets (B) were spaced between monofilament net as indicated in the monofilament string while the multifilament string contained only those nets.

its net components by season, as it had in other years, depending on the season fished and the objectives of the cruise. The standard salmon gill net string normally fished by U.S. research vessels was described by Craddock (1969).

The NMFS research vessel *George B. Kelez* was used for all three of the 1971 cruises. The vessel is an army transport ship, (176 ft [54 m] long), converted for research studies on the ocean distribution of salmon as well as for oceanographic work.

Fishing Procedures and Collection of Biological Data

The net string was set about 2000 hours local time. After setting the nets, the vessel held position within sight of them. Nets were equipped with radiobuoys, strobe light buoys, and lighted buoys to assist the crew in maintaining contact under all weather conditions. The net string was hauled at 0800 hours the following morning.

Salmon, steelhead trout, and other incidental fish caught were then identified as to species, followed by extraction of biological information.

Treatment of Data

Because the comparative fishing effort varied between mono- and multifilament nets, it was necessary to equate effort. All catches were adjusted to CPUE by dividing the catch by the effort (effort is the sum of the nets of a given mesh size and fiber type multiplied by the number of sets fished). The efficiency of monofilament gill nets was derived by using the ratio of monofilament CPUE to multifilament CPUE for each of the compared mesh sizes.

RESULTS

Comparison of Catch Per Unit of Effort

Winter catches were predominantly sockeye salmon, *O. nerka*. Of the gillnet fiber types and of the mesh sizes fished and compared (Table 1), the 3⅞-inch monofilament nets caught the sockeye most efficiently. Compared with similar size multifilament nets, the CPUE was 1.44 and 0.87 as large, respectively, for the 3⅞- and 4½-inch monofilament nets.

In the spring, catches in mono- and multifilament gill nets consisted of sockeye and chum salmon, *O. keta*. The 4½-inch mesh was generally more efficient than the 5¼-inch mesh with the exception of sockeye catches in multifilament nets, owing to the size of salmon available; the 4½-inch monofilament was considerably more efficient than the 4½-inch multifilament nets for both sockeye and chum salmon (Table 1). Monofilament efficiencies were 4.47 and 0.77, respectively, for 4½- and 5¼-inch mesh catches of sockeye salmon and were 2.65 and 0.55, respectively, for chum salmon.

Summer catches in both fiber types included sockeye, chum, chinook, *O. tshawytscha*, pink, *O. gorbuscha*, and

coho salmon, *O. kisutch*, and a large catch of steelhead trout, *Salmo gairdneri*. Monofilament gill nets were more efficient than multifilament with the exception of the 5¼-inch mesh in the latter (Table 1). The comparative efficiency of the mesh sizes of mono- and multifilament gill nets varied slightly by species and decreased as the mesh size increased. The 3¼-inch monofilament was most efficient for catching sockeye and chum salmon — efficiencies were 3.69 and 4.71, respectively. Very few pink and chinook salmon were caught; the most efficient net for both species was 4½-inch monofilament. Coho salmon were most efficiently captured in 5¼-inch multifilament, and steelhead trout were most efficiently captured in 4½-inch monofilament nets.

Table 1. — Comparison of 1971 catches of salmon and steelhead trout in monofilament and multifilament gill nets.

Species	Season	Fiber type	Catch per unit effort[2] Mesh size (inches) 3¼	3⅞	4½	5¼	Monofilament efficiency[3] Mesh size (inches) 3¼	3⅞	4½	5¼
Sockeye	Summer[1]	Monofilament	16.92	12.57	6.57	1.16	3.69	—	1.44	0.83
		Multifilament	4.58	—	4.55	1.40	—	—	—	—
	Winter	Monofilament	—	6.79	5.61	—	—	1.44	0.87	—
		Multifilament	—	4.70	6.42	—	—	—	—	—
	Spring	Monofilament	—	—	12.82	2.53	—	—	4.47	0.77
		Multifilament	—	—	2.87	3.28	—	—	—	—
Chum	Summer	Monofilament	4.24	5.62	4.54	1.30	4.71	—	1.65	1.13
		Multifilament	0.90	—	2.75	1.15	—	—	—	—
	Winter	Monofilament	—	0.00	0.03	—	—	—	—	—
		Multifilament	—	0.02	0.00	—	—	—	—	—
	Spring	Monofilament	—	—	3.47	0.60	—	—	2.65	0.55
		Multifilament	—	—	1.31	1.09	—	—	—	—
Pink	Summer	Monofilament	0.03	0.02	0.05	0.02	—	—	—	—
		Multifilament	0.00	—	0.00	0.00	—	—	—	—
	Winter	Monofilament	—	0.00	0.00	—	—	—	—	—
		Multifilament	—	0.02	0.00	—	—	—	—	—
Chinook	Summer	Monofilament	0.00	0.06	0.11	0.03	—	—	—	0.43
		Multifilament	0.00	—	0.00	0.07	—	—	—	—
	Winter	Monofilament	—	0.00	0.03	—	—	—	—	—
		Multifilament	—	0.00	0.00	—	—	—	—	—
Coho	Summer	Monofilament	0.09	0.24	0.27	0.30	2.25	—	1.69	0.65
		Multifilament	0.04	—	0.16	0.46	—	—	—	—
Steelhead trout	Summer	Monofilament	0.09	0.21	0.56	0.21	4.50	—	3.11	1.31
		Multifilament	0.02	—	0.18	0.16	—	—	—	—

[1] Seasons arranged in this order to show ascending size distributions.
[2] Catch divided by effort.
[3] Monofilament CPUE/multifilament CPUE.

Species Composition

In recent years, the sockeye salmon has been the species of primary interest to NMFS high-seas salmon investigators. Therefore, fishing stations were located in areas where sockeye salmon are known to be abundant; this was reflected by their predominance in the catches. During periods fished, chum salmon were next in abundance. In the areas sampled, coho and chinook salmon and steelhead trout were fewer in number and/or sparse when compared with sockeye and chum (Table 2). The highest catches occurred in summer.

Species composition of catches in the two fiber types was compared. However, data were available for comparison in spring and summer only, since winter catches consisted almost entirely of sockeye. Tests applied to spring and summer catches showed significant difference in composition (Table 3). The differences were due to proportionately larger catches of chum salmon in multifilament nets in spring and of chum and coho in summer.

Table 2. — Species composition of catches in 1971 by fiber type and season.[1]

Season and Fiber type	Sockeye No.	%	Chum No.	%	Pink No.	%	Chinook No.	%	Coho No.	%	Steelhead No.	%	Total
Winter													
Monofilament	484	99.6	1	0.3	0	0.0	1	0.3	0	0.0	0	0.0	486
Multifilament	523	99.6	1	0.2	1	0.3	0	0.0	0	0.0	0	0.0	525
TOTAL	1,007		2		1		1		0		0		1,011
Spring													
Monofilament	614	77.0	183	23.0	0	0.0	0	0.0	0	0.0	0	0.0	797
Multifilament	461	71.9	180	28.1	0	0.0	0	0.0	0	0.0	0	0.0	641
TOTAL	1,075		363		0		0		0		0		1,438
Summer													
Monofilament	1,555	67.1	650	28.1	6	0.3	9	0.4	42	1.8	54	2.3	2,316
Multifilament	1,325	64.1	606	29.3	0	0.0	9	0.4	83	4.0	45	2.2	2,068
TOTAL	2,880		1,256		6		18		125		99		4,384
All seasons													
Monofilament	2,653	73.7	834	23.2	6	0.2	10	0.3	42	1.2	54	1.5	3,599
Multifilament	2,309	71.4	787	24.3	1	0.0	9	0.3	83	2.6	45	1.4	3,234
TOTAL	4,962		1,621		7		19		125		99		6,833

[1] Catches in comparatively fished nets only.

Length Composition

The lengths of the various species of salmon and steelhead trout captured in the two fiber types were compared by examining the average lengths and their variances. This was done to determine if the same portions of the fish populations' length distributions were being taken by both fiber types. In testing for the similarity of average lengths, it must first be assumed that

Table 3.—Chi-square test for independence of species composition and fiber type in gillnet catches by season.

Season	Fiber type	Sockeye	Chum	Pink	Chinook	Coho	Steelhead trout	x^2	d.f.
		Numbers							
Winter									
	Monofilament	484	1	1	1	—	—	—	NO TEST
	Multifilament	523	1	1	1	—	—	—	—
Spring									
	Monofilament	614	183	—	—	—	—	—	—
	Multifilament	461	180	—	—	—	—	4.94[2]	1
Summer									
	Monofilament	1,555	650	6	9	42	54	—	—
	Multifilament	1,325	606	0	9	83	45	27.07[2]	5

[1]Expected values less than 3.0 not used.
[2]Significant at the 0.05 level.

fish captured by one fiber type were taken from populations of the same, or similar, distribution of lengths as fish captured by the other fiber type. Unless this were done, any test of similarity of length would be invalid.

Sockeye salmon in winter, spring, and summer in monofilament gill nets were generally longer. With the exception of 4½- and 5¼-inch nets (spring), significant statistical differences were detected for variances of the length-frequency distributions of sockeye salmon captured in mono- and multifilament nets of comparable mesh size (Table 4).

Chum salmon caught in monofilament nets, on the average, tended to be slightly longer than those caught in multifilament nets of the same mesh in three of five comparisons (Table 4). Significant statistical differences however, were only detected for means in summer catches in 3¼- and 4½-inch mesh nets. Inspection showed a visible difference only in catches in 3¼-inch mesh.

The length means and variances and the length frequency distributions of summer catches of coho salmon in monofilament nets of comparable mesh size were compared (Table 4). No significant differences were detected.

Steelhead trout were captured only in summer in nets being compared. The length means and variances of summer catches in mono- and multifilament nets of the same mesh size were compared (Table 4). No significant differences were detected.

DISCUSSION AND CONCLUSIONS

Most striking in this study is the seasonal variation in the efficiency of mono- over multifilament gill nets for capturing salmon. The efficiencies of 4½-inch monofilament nets for sockeye salmon were 0.89, 4.47, and 1.44 for winter, spring, and summer, respectively. This variation in efficiency was related to the greater effectiveness of the monofilament nets on larger fish, growth of fish during the seasons, and the loss of mature fish to spawning, i.e., changes in the predominant size group of fish available each season. The 4½-inch monofilament net was at its best in spring when the catch was primarily large maturing sockeye salmon. Winter and summer fishing were less efficient owing possibly to a smaller size range of fish available to capture. Most of the larger maturing fish encountered in the spring had departed for the spawning streams before the summer cruise. Since the difference in the size of fish captured in winter in the two types of 4½-inch gill nets is virtually negligible, it appears that the low efficiency of the monofilament nets was due to several factors—the differences in effort (0.6 monofilament to 1 multifilament) and the relation between effort and number of fish available to capture. Also, a good proportion of the fish encountered were probably able to swim through the monofilament nets (owing to greater stretch qualities), whereas they were detained in the multifilament nets.

The 3⅞-inch mesh was only fished comparatively in winter. The comparative efficiency of mono- to multifilament gill net for catching sockeye salmon was 1.44 (negligible numbers of other species were captured). Assuming individual sockeye salmon in

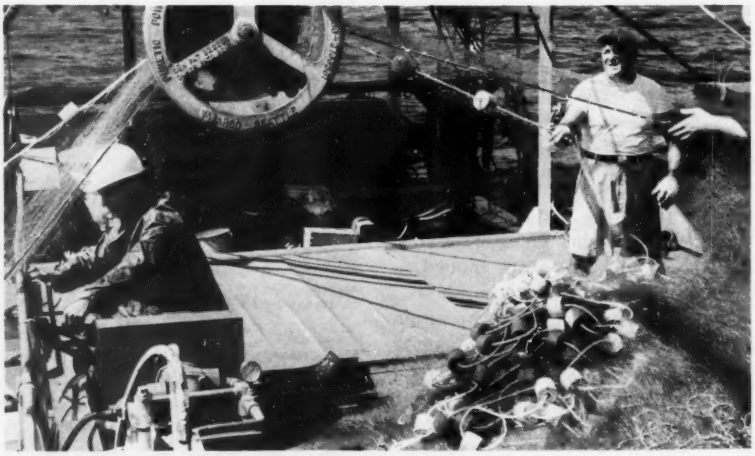

Figure 3.—Hauling back a gill net, the primary tool in the National Marine Fisheries Service research cruises studying distribution of the Pacific salmon in the North Pacific and the Bering Sea.

North Pacific populations are scattered in winter (French and McAlister, 1970) and if there is less tendency for schooling or congregation at lower light intensities, as with other schooling species (Whitney, 1969), catches could be considered quite good.

The monofilament gill net, in light of the data presented herein, must be regarded as a good sampling tool in high-seas salmon investigations. When fished on a comparative basis with the multifilament gill net, it has proven at least equal under all conditions examined. Total efficiency of monofilament compared with multifilament (all species in all seasons) was 2.0. This figure, however, should not be considered a measure of fishing power.

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Table 4.—Tests for differences in length means and variances of mono- and multifilament gillnet catches by species, mesh size, and season, 1971.

Species and season	Mesh size (inches)	Fiber type	Sample size (N)	Mean length (cm) ($\bar{X}$)	Variance S^2	$\frac{S^2 max}{S^2 min}$	Significant[1]	t	Significant[1]
Sockeye									
Winter	3⅞	Monofilament	264	50.2	14.19	1.26	yes	—	—
		Multifilament	220	50.1	11.22	—	—	—	—
	4½	Monofilament	219	53.2	11.57	1.26	yes	—	—
		Multifilament	300	53.2	14.56	—	—	—	—
Spring	4½	Monofilament	497	56.2	11.24	1.07	no	1.08	no
		Multifilament	213	55.9	10.50	—	—	—	—
	5¼	Monofilament	111	57.7	7.85	1.08	no	0.91	no
		Multifilament	241	57.4	8.47	—	—	—	—
Summer	3¼	Monofilament	1,041	42.8	33.19	1.47	yes	—	—
		Multifilament	557	39.6	22.50	—	—	—	—
	4½	Monofilament	402	51.2	7.54	1.50	yes	—	—
		Multifilament	552	50.6	11.34	—	—	—	—
	5¼	Monofilament	79	53.0	8.16	3.42	yes	—	—
		Multifilament	174	52.6	27.90	—	—	—	—
Chum									
Spring	4½	Monofilament	156	55.4	7.83	1.13	no	1.12	no
		Multifilament	98	55.0	6.95	—	—	—	—
	5¼	Monofilament	27	56.6	8.39	1.06	no	0.32	no
		Multifilament	82	56.8	7.95	—	—	—	—
Summer	3¼	Monofilament	279	46.8	31.89	1.02	no	7.56	yes
		Multifilament	113	42.1	32.69	—	—	—	—
	4½	Monofilament	281	53.7	17.46	1.13	no	2.38	yes
		Multifilament	339	52.9	19.77	—	—	—	—
	5¼	Monofilament	79	57.7	18.69	1.20	no	0.61	no
		Multifilament	145	58.1	22.52	—	—	—	—
Pink	(INSUFFICIENT DATA)								
Chinook	(INSUFFICIENT DATA)								
Coho									
Summer	3¼	Monofilament	5	62.0	8.00	1.37	no	0.73	no
		Multifilament	4	63.5	11.00	—	—	—	—
	4½	Monofilament	17	58.8	22.40	1.25	no	0.35	no
		Multifilament	18	59.4	28.02	—	—	—	—
	5¼	Monofilament	19	60.6	6.70	1.49	no	0.25	no
		Multifilament	58	60.8	10.01	—	—	—	—
Steelhead									
Summer	3¼	Monofilament	6	57.0	(INSUFFICIENT DATA)				
		Multifilament	2	68.5	—	—	—	—	—
	4½	Monofilament	35	62.0	35.88	1.31	no	0.82	no
		Multifilament	23	60.6	46.88	—	—	—	—
	5¼	Monofilament	12	65.6	78.45	1.85	no	0.55	no
		Multifilament	20	64.1	42.30	—	—	—	—

[1] Significant at the 0.05 level.

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MFR PAPER 997

Off the glorious Kona coast of the Island of Hawaii, sportsmen and scientists have gathered for 11 summers to study the habits of the billfish.

Investigations of Billfish Biology at the Hawaiian International Billfish Tournament

JOHN J. NAUGHTON

ABSTRACT

Since 1962 the Southwest Fisheries Center's Honolulu Laboratory, National Marine Fisheries Service, has sent an investigating team to the annual Hawaiian International Billfish Tournament. There the team collected biological data for marine sport fisheries research. This paper outlines the tournament and NMFS participation and summarizes data collected there from 1962 to 1972. In order of abundance, billfish species taken by tournament anglers were Pacific blue marlin, Makaira nigricans; *striped marlin,* Tetrapturus audax; *black marlin,* M. indica; *sailfish,* Istiophorus platypterus; *and shortbill spearfish,* T. angustirostris. *Yellowfin tuna,* Thunnus albacares, *weighing 100 lb. or more also qualified and was the second most abundant game fish species taken. Results of investigations are discussed including marlin diet, sex ratio, sexual dimorphism, fishing effort, and marlin movements on the fishing grounds.*

INTRODUCTION

The Hawaiian International Billfish Tournament (HIBT) has been conducted off the west (Kona) coast of the island of Hawaii every summer since 1959. Beginning in 1962, the Southwest Fisheries Center's Honolulu Laboratory, National Marine Fisheries Service (NMFS), has sent an investigating team to each tournament to collect biological data from billfish taken by tournament anglers. This paper outlines the Honolulu Laboratory's participation in the tournament, describes the methods of collecting data, and presents a summary of these data.

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THE TOURNAMENT

The HIBT is an 8-day event held each year during the summer months, usually July or August. Fishing is done for 5 days, Monday through Friday, from 8 a.m. to 5 p.m. Some 50 to 85 select foreign and U.S. teams participate, with Hawaiian teams comprising a large part of the U.S. representation. Each team consists of up to six members, with any four permitted to fish on a given day.

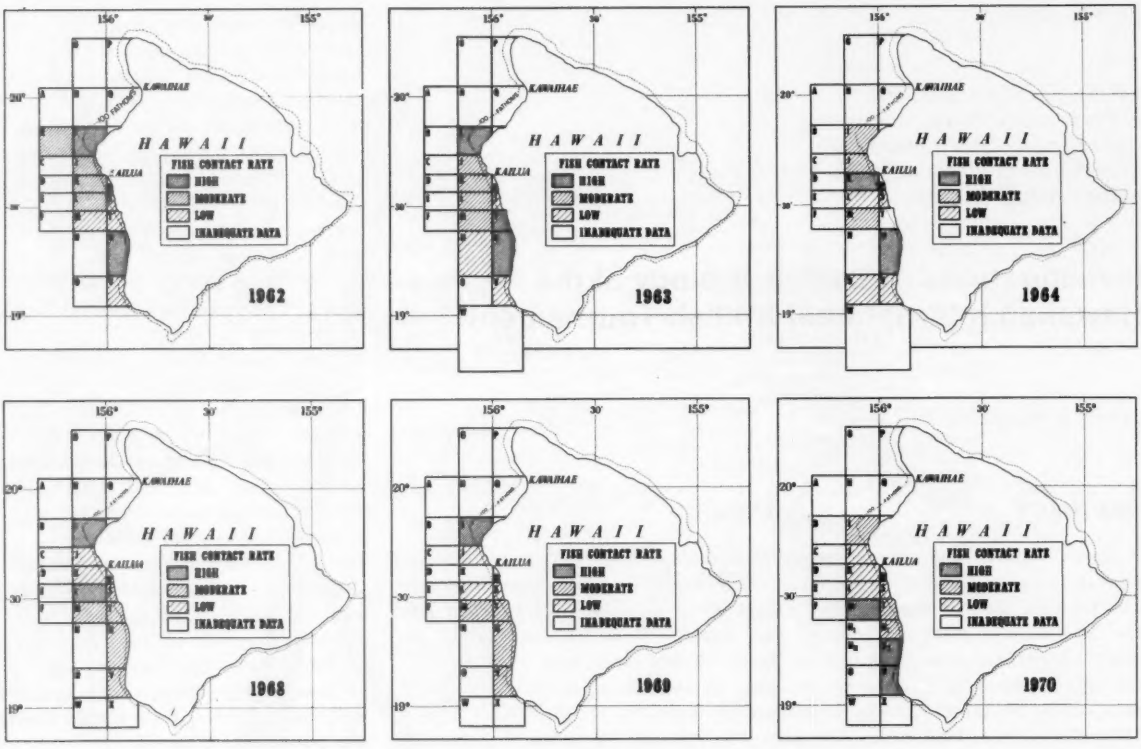
Trolling artificial lures at 5 to 8 knots or live bait at either very slow speeds or while drifting are the two methods of fishing allowed. International Game Fish Association rules are strictly adhered to. Fishing is done from individually owned or chartered trolling boats ranging in length from 16-ft outboards to 50-ft diesel powered sampans. Only fish caught on rod and reel qualify. Handlines are permitted solely for the catching of bait.

The fishing area extends the entire length of the west coast (Kona Coast) of the island of Hawaii. A grid system divides it into 26 different areas (Figure 1). All fish submitted for scoring are landed at the pier in Kailua-Kona and weighed on the official scale. Anglers fill out prize entry forms and exhibit the bait, rod, reel, gaff, and tackle with which their fish were caught, as well as furnish names of all witnesses.

Although the tournament is a billfish tournament, tuna weighing 100 lb. and over qualify. The yellowfin tuna, *Thunnus albacares*, is the predominant species of large tuna taken by trolling in Hawaiian waters and the only species weighing over 100 lb. recorded from the tournament catch.

Scoring in the HIBT is as follows:

1. Marlin competition is on a team basis.
2. Tuna competition is on an individual basis.
3. The basic award in both divisions is one point per pound.
4. There is a 30% bonus for marlin caught on 80-lb. test line.
5. There is a 100% bonus for marlin caught on 50-lb. test line.
6. There is a 100-point bonus for the largest marlin of the day.
7. There is a 100-point bonus for the largest marlin of the tournament.
8. Bonus points for the largest fish of the day and the tournament are awarded on the basis of the weight of the fish exclusive of any bonus points for line strength.
9. In the event of a tie for the biggest fish of the day or the tournament, bonus points will be divided evenly.
10. In case of a tie in points at the conclusion of the tournament in the billfish division, the team having



caught the largest fish of the tournament will be declared the winner.

PARTICIPATION BY THE NATIONAL MARINE FISHERIES SERVICE

At least one staff member from the Honolulu Laboratory, NMFS, is at the tournament each year in an official capacity as tournament biologist. Prior to each tournament he prepares a newsletter which is distributed to all participating anglers. It asks for their continued cooperation and outlines exactly what data will be collected at the tournament that particular year. The biologist sets up a display at tournament headquarters depicting fishery research activities carried out by the Honolulu Laboratory. He presents a talk at the pre-tournament briefing session for charter boat skippers and competitors, again going over what data will be collected and assuring anglers that no fish will be touched without the angler's permission.

During fishing days the biologist compiles fish contact and fishing effort data by monitoring the three daily radio reports transmitted to tournament headquarters by the fishing fleet. Tabulation of these data enables a fish contact rate chart to be compiled for each tournament (Figure 1).

After the fish are landed they are hoisted and weighed. At this time the biologist assists in the species identification. The fish are then transported to an observation area where the biologist takes morphometrics, dissects the fish for stomach content analysis, determines sex and condition of gonads, and carries out other specific sampling, e.g., collecting different tissues for determination of mercury content.

The weigh-in activities are of great interest to tourists and residents, and large crowds accumulate on the pier. Bleachers are set up for spectators, and an announcer describes weigh-in activities. The biologist periodically provides the announcer with the results of his examinations, such as the stomach contents and sex of each fish and other information of possible interest to the spectators. A variety of questions on billfish biology and fishery biology in general are often directed by the spectators to the biologist. The tournament participants themselves ask many questions of the same nature. The attending biologist must have therefore an up-to-date recall of basic as well as specific information concerning billfish and research programs of the Honolulu Laboratory.

Upon completion of the tournament

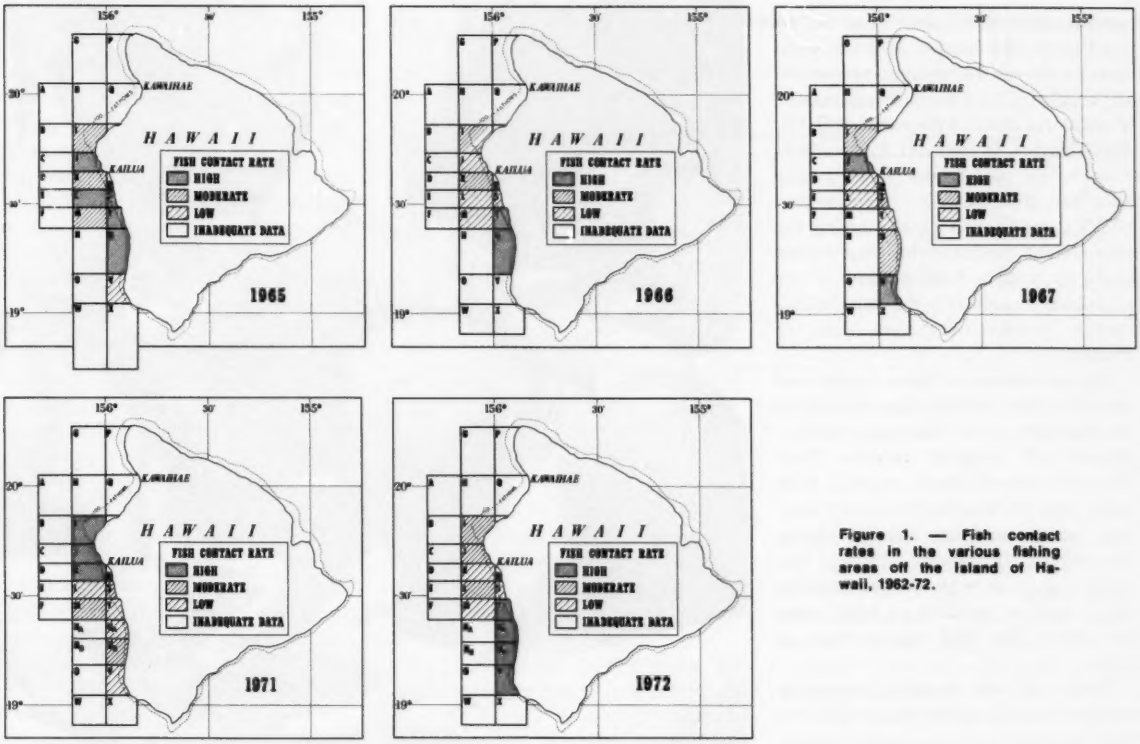


Figure 1. — Fish contact rates in the various fishing areas off the Island of Hawaii, 1962-72.

the biologist compiles a report.[1] describing the results of his investigations. This report is sent to all tournament participants, charter boat captains, and tournament staff.

During recent tournaments biologists on the Honolulu Laboratory's research vessel *Charles H. Gilbert*, working in conjunction with local charter boats, have been involved in tracking marlin for studies of their movements in Kona waters. The tags used in tracking are acoustic transmitters which are temperature sensitive. Thus, the water temperature around the fish may be determined by measuring the pulse rates. By combining this information with data on the temperature-depth profile of the water, the depth of the marlin can be determined.

Tracking is generally done during the week prior to the tournament. Once a marlin is hooked by the smaller, more maneuverable charter boat, the research vessel is contacted and alerted for tracking. As quickly and carefully as possible the marlin is brought alongside, where its condition is checked and its size estimated. If it appears to be in good condition the transmitter is attached to the dorsal surface of the marlin with a small anchor plate inserted just beneath the tough skin. The fish is released, and tracking begins.

In earlier tournaments large plastic drift panels were released in the fishing area by Honolulu Laboratory research vessels as part of a study of the surface currents off the Kona Coast. Whenever a panel was sighted by a tournament fishing boat its position was radioed back to headquarters. This enabled the NMFS biologist to plot the movements of the panels while they stayed on the fishing grounds. These experiments were carried out for five consecutive tournaments (1965-69) with excellent cooperation received from both charter boat captains and tournament anglers. Results confirmed the existence of a pair of large eddies in the fishing area, the northern one rotating counterclockwise and the southern rotating clockwise. Attempts to correlate fishing success with different features of these currents yielded no conclusive information; therefore, the drift panel experiments were terminated.

RESULT OF INVESTIGATIONS

The Catch

The total catches of qualifying game fish for the HIBT from 1962 to 1972

[1]Report to participants of the Hawaiian International Billfish Tournament from 1962 to 1972. Mimeogr. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812

are documented in Table 1. For billfish, the Pacific blue marlin, *Makaira nigricans*, made up the greatest proportion of the catch (72.4%) with striped marlin, *Tetrapturus audax*, a poor second (2.1%). Black marlin, *M. indica* (1.3%), sailfish, *Istiophorus platypterus* (0.4%), and shortbill spearfish, *T. angustirostris* (0.2%) were taken rarely during the tournament. Because the blue marlin made up such a high percent of the tournament catch it is the only billfish species yielding sufficient data to discuss.

The abundance of blue marlin and lack of striped marlin taken during the tournaments is not surprising. Investigations of longline catches from Hawaiian waters clearly reveal a high catch rate for blue marlin during summer months and low catches during the winter (Strasburg, 1970). The reverse is true with striped marlin, which tend to be taken in large numbers when the blue marlin catch is lowest.

There are two possible factors to explain this segregation of species. The most probable is temperature. Striped marlin tend to live in cooler waters; therefore they move north in the summer (Howard and Ueyanagi, 1965), while the blue marlin possibly replace them from the south. Although trolling records are poor for year-round billfish catches in Hawaiian waters, personal observations indicate a substantial number of blue marlin taken by trolling even in the winter months. This tends to substantiate temperature as a major segregating factor, assuming those blue marlin that are still in Hawaiian waters remain in the warmer surface waters during winter and are therefore more susceptible to trolling and less to deep fishing longline gear.

Another factor which may explain this segregation is food supply. As discussed below, stomach contents of blue marlin caught during the tournament contain a high percentage of tuna, while striped marlin seem to prefer a variety of smaller fish, squid, and crustaceans. It has been shown that seasonal distribution of blue marlin and skipjack tuna, *Katsuwonus pelamis*, in Hawaiian waters coincide quite well (Strasburg, 1970). This would indicate that the appearance of large numbers of blue marlin may be related to the presence of one of their primary forage species.

It is not surprising that black marlin and sailfish are low in the tournament catches, since they are primarily found near continental land masses (Howard and Ueyanagi, 1965). Both are taken infrequently by local commercial longline vessels. The shortbill spearfish is rarely taken trolling although it is often seen in the local longline catches. This would indicate a subsurface exis-

Biologists John J. Naughton (left) and Robert T.B. Iversen examine stomach contents of fish caught at Hawaiian International Billfish Tournament.

tence for this species, at least in Hawaiian waters. The same is true for the swordfish, *Xiphias gladius*, which yields no record of having been taken by trolling in Hawaii, yet during late spring and early summer is common in local longline catches.

Yellowfin tuna weighing 100 lb. and greater is the second most abundant sport fish taken during the tournaments, as evidenced in Table 1 (23.6%). In fact, in 1971 it was the most abundant species in the catch. Generally these large yellowfin are more commonly caught by trolling in Hawaii during the summer months when the tournament is held. However, they can be taken year-round with spectacular runs developing at any time.

Table 1. — Numbers of qualifying game fish landed and teams fishing during Hawaiian International Billfish Tournaments, 1962-72.

Year	Blue marlin	Black marlin	Striped marlin	Shortbill spearfish	Sailfish	Yellowfin tuna ⩾ 100 lb.	Total qualifying fish	Number of teams	Number of boat days fishing per fish
1962	30	1	—	—	1	19	51	68	6.7
1963	19	2	1	—	—	26	48	72	7.5
1964	31	—	1	—	—	2	34	69	10.1
1965	47	—	—	—	—	9	56	78	6.9
1966	26	3	2	—	—	7	38	72	9.5
1967	63	—	1	—	—	18	82	68	4.2
1968	36	2	4	—	—	4	46	85	9.2
1969	32	1	—	—	—	4	37	75	10.1
1970	91	—	2	—	2	14	109	73	3.3
1971	41	—	3	1	—	47	92	77	3.4
1972	77	—	—	—	—	11	88	59	3.4
Total	493	9	14	1	3	161	681	72*	6.8*
Percent of catch	72.4	1.3	2.1	0.2	0.4	23.6	100		

*Average.

Marlin Diet

Although billfish show great variations in dietary trends between different species as well as among separate populations of the same species (Strasburg, 1970), they are often quite consistent in their diets from any one area. The blue marlin stomach contents examined at the tournaments match contents of blue marlin caught on local longline, in that smaller scombrids (skipjack, yellowfin, kawakawa, *Euthynnus affinis*, and albacore, *Thunnus alalunga*), carangids, and squid predominate. During some tournaments, however, a sudden change occurs in their diet when an influx of uncommon forage items appears on the fishing grounds. As an example, during the 1972 tournament (Table 2), the young of a goatfish, *Mulloidichthys* sp., and a species of spiny puffer, Diodontidae, obviously became important food items, ranking comparably with the more conventional blue marlin food. It would appear, therefore, that blue marlin in Hawaiian waters feed on whatever forage species are available.

Some of the more unusual stomach contents from tournament-caught blue marlin have included juvenile billfish (including swordfish), deepwater lancetfish (Alepisauridae), and a 63-lb. bigeye tuna, *T. obesus*, found in the stomach of a 748-lb. blue marlin. The occurrence of deepwater lancetfish in very fresh condition indicates that blue marlin may be feeding at considerable depths during the day.

The few striped marlin from the tournament that have been examined usually contain pelagic stages of reef fish, squid, and crustaceans in their stomachs. Invariably the angler who takes an unusual billfish species (sailfish or shortbill spearfish) wants it mounted for a trophy; therefore, they rarely are dissected.

Table 2. — Stomach contents of blue marlin, *Makaira nigricans*, from Hawaiian International Billfish Tournament, 1972.

Food items		Day and number of stomachs containing listed food items					Percentage of occurrence
		August					
		7	8	9	10	11	
Fish							
Tuna	Scombridae						
Skipjack	*Katsuwonus pelamis*	—	—	—	1	1	3
Kawakawa	*Euthynnus affinis*	—	—	—	1	—	1
Unidentified		2	7	9	5	5	39
Mahimahi	Coryphaenidae	—	—	4	—	4	11
Jacks	Carangidae						
Opelu	*Decapterus pinnulatus*	—	2	2	1	3	11
Unidentified		1	—	—	—	1	3
Lancetfish	Alepisauridae	—	—	—	1	1	3
Goatfish	Mullidae						
Oama	*Mulloidichthys* sp.	2	3	2	4	4	21
Cardinalfish	Apogonidae	—	—	—	1	—	1
Squirrelfish	Holocentridae	—	—	2	1	—	4
Surgeonfish	Acanthuridae	—	—	—	—	1	1
Bonnetmouth	Emmelichthyidae	1	—	—	—	—	1
Pelagic spiny puffer	Diodontidae	3	6	7	2	4	31
Puffer	Tetraodontidae	—	1	—	—	—	1
Unidentified fish							
Large >12 inches		—	—	2	2	—	6
Small <12 inches		1	2	7	4	3	24
Invertebrates							
Squid	Decapoda	1	8	9	4	6	39
Empty or everted stomachs		3	2	1	5	2	18
Number of blue marlin examined Total: 72		11	17	17	17	10	—

Sex Ratio and Sexual Dimorphism

An unusual phenomenon noted from blue marlin catches in the tournament is the high ratio of males to females (Table 3). A random sample of 694 blue marlin from the Hawaiian longline catch consisted of 334 males and 360 females (Strasburg, 1970). Only during the 1964 tournament, however, did the sex ratio approach this expected 1:1 condition. It would seem that during the other 10 tournaments the blue marlin were segregated by sex on the fishing grounds.

Tournaments which produced the highest numbers of blue marlin (1965, 1967, 1970, 1972) also revealed the largest male to female ratios (4.4:1, 3.9:1, 4.5:1, and 8.0:1, respectively). The 8:1 ratio from the 1972 tournament catch is especially noteworthy. The unusual abundance of male blue marlin during these years was a major factor contributing to the success of those particular tournaments. Whether this surplus of males is due to fishing gear selectivity, a feature of reproduction or feeding behavior, or some other unknown factor is not yet known.

The weights of the 493 blue marlin caught in the tournaments from 1962 to 1972 ranged from 48 to 809 lb. Males ranged from 48 to 377 lb. whereas females were from 96 to 809 lb. Blue marlin, as well as black marlin, are known for their marked sexual dimorphism, with females attaining a much larger size (Royce, 1957). A general rule is that a blue marlin heavier than 300 lb. is a female. Of the 340 males taken during the tournaments only three were over 300 lb., weighing 309, 314, and 377 lb. each.

Table 3. — Sex ratios for blue marlin, *Makaira nigricans*, examined from Hawaiian International Billfish Tournaments, 1962-72.

Year	Number of males	Number of females	Ratio males to females
1962	16	7	2.3:1
1963	13	6	2.2:1
1964	14	12	1.2:1
1965	35	8	4.4:1
1966	16	8	2.0:1
1967	51	13	3.9:1
1968	24	10	2.4:1
1969	23	8	2.9:1
1970	63	14	4.5:1
1971	21	9	2.3:1
1972	64	8	8.0:1
Total	340	103	3.3:1*

*Average.

Fishing Effort

Team radio reports are given at 10 a.m., 12 noon, and 3 p.m. Each team reports fishing areas and time spent in each, number of strikes, hook-ups, or boated fish since the last report, and the area of its reported fish contacts. Fishing effort is measured by fish contact per boat hour by fishing area. Each fish contact is counted only once as either a strike, hook-up, or boated fish. Allowance is made for the different lengths of the reporting periods and for the varying number of boats in each period and area. Only those areas in which five or more boats fished for one or more reporting periods are assigned a final rating.

The distribution of fish contact rates by fishing area for the 1962 to 1972 tournaments is shown in Figure 1. Often areas that produced the greatest catches did not necessarily have the highest fish contact rates. For example, area I produced the most blue marlin in 1972, but in final tabulation it only warranted a moderate contact rating (Figure I). This indicates that fishing effort was more intense in I, but that if the same boats had ventured south during the tournament to areas T, U_A, U_B, or V, their chances of taking a fish would have been better.

The last column in Table 1 summarizes fishing effort for the HIBT from 1962 to 1972. When number of boat days fishing per fish landed are considered, the 1967, 1970, 1971, and 1972 tournaments are all well below the average of 6.8 boat days per fish. As mentioned previously an influx of male blue marlin appears to be responsible for the success of three of these four tournaments. The exception, the 1971 tournament, was successful because of a tremendous run of large yellowfin tuna that year.

Another factor which perhaps contributed to the success of these tournaments was tidal phase. The NMFS biologists have been plotting fish contact rates against tidal cycle for most of the tournaments. Early observers noted from these data a suggestion that fishing for the most part was better during a rising tide with maximum range, such as that associated with a new moon. These observations were confirmed by charter boat captains and several tournament staff members. Because of this, recent tournaments have been scheduled to coincide with this feature of the tidal cycle, and, as can be seen from Table 1, the last three tournaments have been most successful.

Marlin Movements on Fishing Grounds

One week prior to the 1971 and 1972 tournaments five blue marlin were tagged with sonic tags and tracked: one during July 14-15, 1971 and four between July 25 and 28, 1972. Following is a summary of these tracking experiments from Yuen (in press). The first tagged marlin was tracked for 22 hr and 25 min before a malfunction in the tracking equipment forced a halt (Figure 2). This fish was a blue marlin estimated to weigh 600 lb. The second marlin was in doubtful condition when released and was difficult to track. Contact was lost after an hour. The third fish was tracked for 5 hr and 22 min before it was lost owing to a tactical error. The fourth marlin was abandoned after 7 hr when it remained stationary on the bottom soon after it was tagged, indicating that in all probability it had died. After 2 hr of swimming, the fifth marlin also went to the bottom.

Several features stand out from the marlin tracking studies. All viable marlin showed indication of staying above precipitous bottom, in this case between the 100- and 1,000-fathom iso-

baths. Although usually well above these depths, they apparently could sense some feature of the rapidly sloping escarpments far beneath them. The viable marlin also all moved in a northerly direction when released. From the drift panel studies it was determined that the current system west of the northern half of the island of Hawaii forms a counterclockwise eddy during the summer months with the inshore portion flowing northward. All marlin tracked appeared to be in this current system, and the fact that they moved north suggests the possibility that blue marlin orient or swim with currents. Swimming depths were quite different among the marlin tracked, ranging from the surface to 185 m. Vertical movements showed no pattern that could be related to time of day.

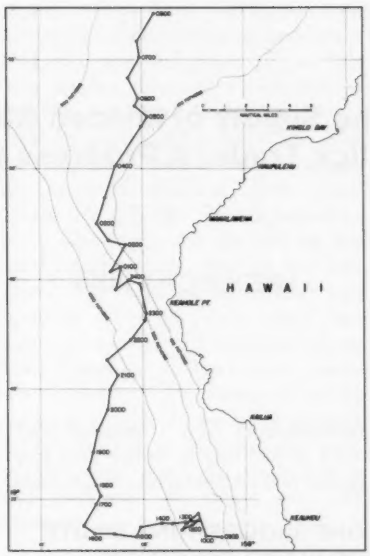


Figure 2. — Track of tagged Pacific blue marlin (ca. 600 lb.) during July 14-15, 1971. Positions on track taken at half-hour intervals.

CONTINUED INVESTIGATIONS

The HIBT has a long history of sports fisherman-scientist cooperation. This was highlighted by the unique International Billfish Symposium held to coincide with the 1972 tournament (Anonymous, 1972). Because relatively little is known concerning the status of billfish, both from a commercial as well as a sport fishing point of view, it is important to monitor these periods of intensive sampling that occur during tournaments. A substantial number of billfish tournaments are held throughout the world every year. It would be helpful if scientific investigations could be carried out at each tournament on a continuing basis.

ACKNOWLEDGMENT

I would like to thank Mr. Peter Fithian and the other members of the Board of Governors, HIBT, for their continuing cooperation in helping us collect data at the tournaments. I am also indebted to the charter boat captains and tournament anglers who provide fishing statistics and allow us to examine their catches.

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MFR PAPER 998

Improving the Supply of Minced Blocks for the Fish Stick Trade: A Progress Report

FREDERICK J. KING

BACKGROUND

The scarcity of fish blocks and the increasing demand for fish sticks have prompted us to develop a process for making minced blocks using fish frames (a fish backbone after fillets have been removed). At present, these frames are utilized for meat or fertilizer even though their flesh is essentially the same as the flesh of the fillets cut from them. Besides this white flesh, the frames contain blood-rich tissues right under the backbone. Since these tissues are as soft as the white muscle, they will pass through with it in a meat-bone separator. The blood pigments will give the minced flesh a red color (similar to ground beef) or if they become oxidized, a brown or gray color. In a fish stick, any color other than white is usually considered as a defect.

A marketplace for fish sticks made from minced flesh has already been established. These sticks are made from minced flesh obtained from V-cuts (fillet trimmings) which do not contain visible blood pigments. The yield of edible meat from this source is only about 2 percent of the carcass weight. In contrast, fish frames contain about 20 percent machine-separable flesh (based on carcass weight). These considerations have stimulated R&D work to find how to utilize flesh from frames in the manufacture of fish sticks.

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ONE SUGGESTION—DILUTE OR BLEND THE COLOR

We found that the intensity of the blood color in minced blocks could be reduced by dilution. For example, if headed and gutted fish are passed through a meat-bone separator, the minced flesh will be whiter because it contains a greater proportion of white muscle. A similar method of dilution is to mix fillet trimmings or V-cuts with the frames and pass this mixture through a meat-bone separator. This method saves the fillet meat for sale as regular fillets; but it, too, does not decolorize the blood pigments specifically. We have also used selective cuts from frames (such as tail sections, belly flaps, etc.) to avoid passing the blood-rich tissues through a separator. This method does reduce the intensity of color in the minced flesh. It also reduces the yield of edible meat from the carcass and introduces the costs of making the selective cuts.

Another method of increasing the whiteness of minced fish flesh is to blend it with a suitable flour or a similar white vegetable product. This method has been used by Japanese firms for several years in making traditional products such as kamaboko (Tanikawa, 1971). It can be applied to occidental seafood products such as fish cakes. However, it is obviously not suitable for the manufacture of all-fish-flesh products.

ANOTHER SUGGESTION—WASH OUT THE COLOR

None of the above methods attempts specifically to decolorize or remove the colored blood pigments. Chemical additives such as hydrogen peroxide or sodium hypochlorite can whiten fish flesh, but their employment can introduce unacceptable deterioration in texture and flavor. The Japanese method of making minced fish blocks (surimi) involves washing minced flesh with copious amounts of water after it has been separated from bone and skin as well as using headed and gutted fish to obtain the minced flesh (Tanikawa, 1971). The advantages of this method of leaching blood pigments from minced fish flesh prompted us to study its adaptability for making minced blocks from fish frames or headed and gutted fish that would be suitable for the manufacture of fish sticks.

TEST METHODS FOR WASHING SUGGESTION

This method of preparing minced fish blocks is based on the following sequence of steps:

1. Remove heads and viscera (if present) from frames or whole fish.

2. Pass raw material through a meat-bone separator and wash the flesh while it is being separated.
3. Dewater the minced flesh.
4. Pass dewatered flesh through a strainer.
5. Prepare minced fish blocks from the strained material.

Several species have been used so far in these tests. Filleting leftovers (backbones or frames) have included: cod *(Gadus morhua)*, tom cod *(Microgadus tomcod)*, cusk *(Brosme brosme)*, flounder, mixed *(Pseudopleuronectes americanus, Limanda ferruginea, Hippoglossoides platessoides,* and *Glyptocephalus cynoglossus)*. Headed and gutted species have included: whiting *(Merluccius bilinearis)*, ocean perch *(Sebastes marinus)*, and herring *(Clupea harengus)*. Fresh water species (all headed and gutted) have included: carp *(Cyprinus carpio)*, sucker *(Catostomus commersonni)*, sheepshead *(Aplodinotus grunniens)*, and white amur *(Ctenopharyngodon idellus)*. With the exception of herring, the edible flesh of these species consists mostly of white muscle with a small amount of dark, lateral line muscle. Again, with the exception of herring, we found that species differences were less important than our processing and handling variables in influencing the quality of our minced blocks.

Heading and Gutting

Removal of heads and viscera (if the fish were not gutted at sea) is presently done by hand labor. Using a band saw to cut off the heads has increased productivity but heading and gutting equipment would be more satisfactory. Such equipment is available for certain species or sizes and shapes, but there is a need for more versatile heading and gutting equipment to match the versatility and throughput of meat-bone separators.

Flesh Separation and Washing

Flesh can be removed from skin and bone in a variety of commercially available meat-bone separators. We are using a Bibun Model 15 separator[1] (Figure 1; see also Figures 2, 3, and 4). This machine contains a wide flexible belt that moves against the outside of a rotating, perforated metal drum. The belt and drum move at different speeds in the same direction. Since these speeds are different, flesh is separated by a shearing action as well as the mechanical pressure between belt and drum. The flesh passes through the holes of the drum while bones and skin are dumped off the end of the belt. Although we have used drums with 3 mm or 5 mm holes, we settled on a drum with 7 mm holes in most of our testing to increase the yield of recovered flesh and to minimize fragmentation of bones in the separator.

[1]The mention of commercial items does not constitute an endorsement by the Department of Commerce over other items of a similar nature not mentioned.

We have found that washing the flesh as it is being separated from bones and skin offers several advantages. The most obvious one is that it leaches a significant amount of blood before the blood clots and becomes insoluble in water. Washing also hastens movement of flesh down the drum and out of the machine. Originally, we used a garden hose with an adjustable nozzle and sprayed the water by hand into the flesh-packed holes of the moving drum. More recently, we mounted adjustable nozzles on the separator itself to eliminate this requirement for hand labor. The amount of water used has been in the order of 2 to 3 times the weight of dewatered minced flesh obtained. This amount of water is considerably less than the ratios of about 7 or more

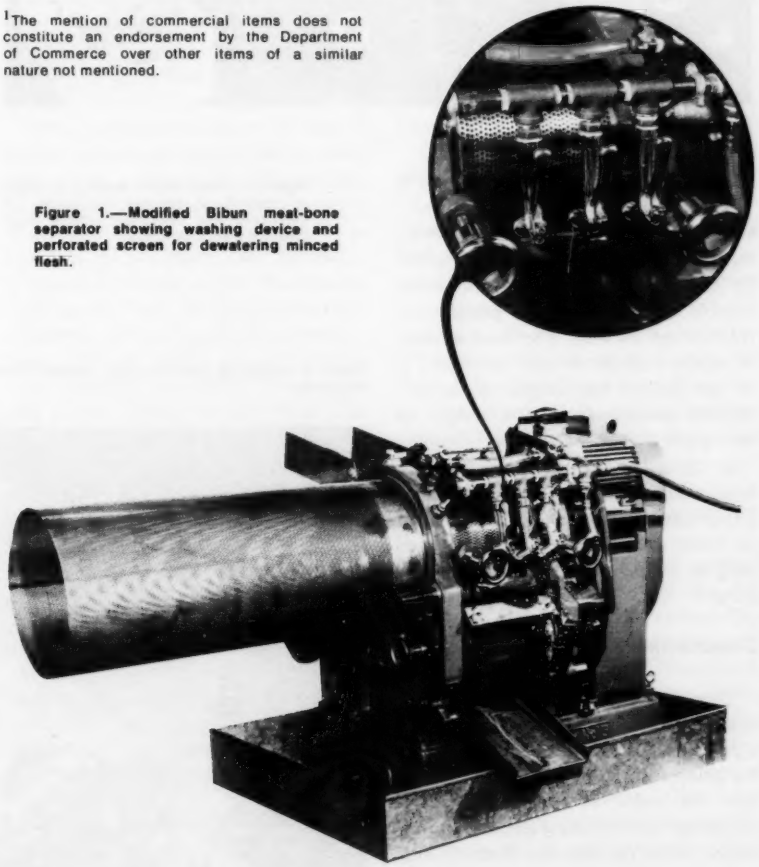


Figure 1.—Modified Bibun meat-bone separator showing washing device and perforated screen for dewatering minced flesh.

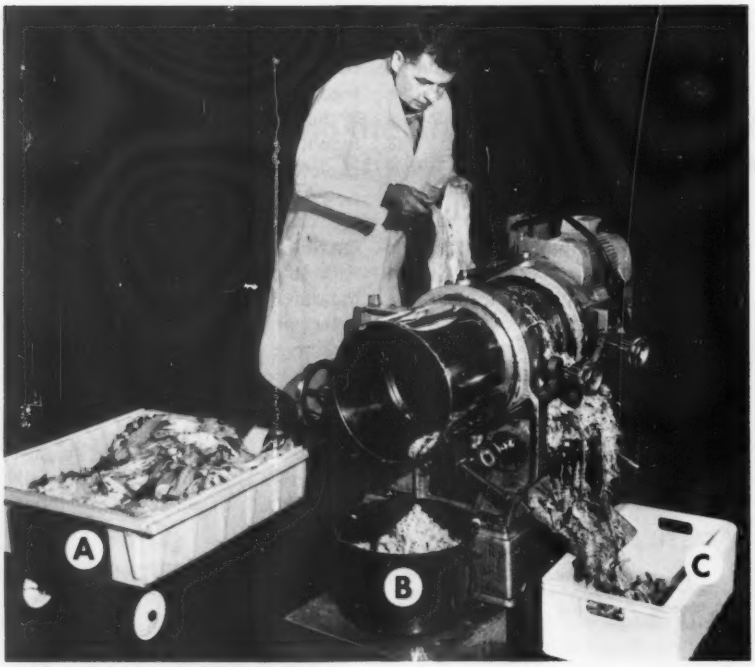


Figure 2.—This Bibun separator is being used to separate minced flesh from filleting leftovers (fish frames), shown at A. The recovered minced flesh is shown at B, the waste at C. This is the machine of Figure 1 without the washing device and the dewatering screen.

Figure 3.—The Bibun strainer is used, as desired, to improve the quality of dewatered and unwashed minced flesh obtained from a separator.

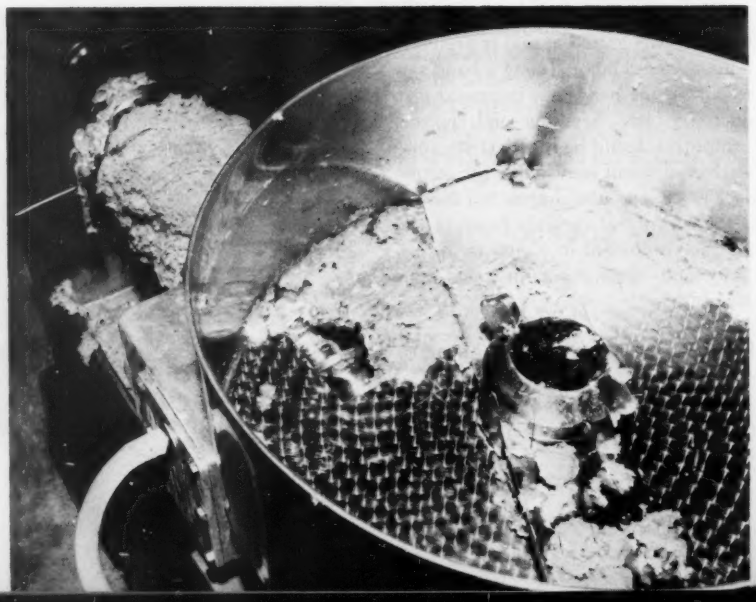
to 1 used by Japanese technologists in washing minced flesh to make surimi.

Although our purpose in washing the minced flesh was to reduce color by removing blood pigments, other soluble components were presumably leached out as well. The total amount of solids washed out was estimated at 10 percent of the weight of the unwashed minced flesh. The weight of the washed flesh itself was variable. The capacity of muscle proteins to hold water is well known. This capacity is affected by particle size, amount of water used, intimacy of mixing as well as temperature, and time conditions.

Dewatering

Dewatering the minced flesh is the next step in the process. We have put a perforated screen around the end of the drum in the separator. This screen has ⅛-inch holes and is 3 feet long. Most of the water which was mixed with the minced flesh in the

Figure 4.—Close-up view of Bibun strainer to show separation of minced flesh from skin or bone fragments.



drum drops out during the first third of the minced flesh's travel down this screen. How much water to remove from the minced flesh which drops off this screen and what equipment to use for this dewatering are two problems for which we have only partial answers at the present time.

Removal of excess water is necessary from a technological as well as a consumer viewpoint. For example, in the manufacture of fish sticks, the blocks from which these sticks are cut should have less than 5 percent "drip" (a measure of excess water). If these blocks have more than 5 percent excess water, sticks made from them tend to have too loose a coating of batter-breading and are apt to "explode" during cooking.

On the other hand, removal of too much moisture from minced flesh can accelerate deterioration of the flesh during frozen storage. The relation of moisture content or water activity to rate of lipid oxidation has been worked out in several model system studies as well as in various foods (review by Karel and Flink, 1973). The irreversible denaturation of fish muscle proteins, especially the myofibrillar protein, during frozen storage has been studied from this and other aspects (reviews by Connell, 1968; Dyer, 1968). The rate of this denaturation or loss of water holding capacity might be slowed down by holding the muscle protein under more favorable conditions (King, 1966). To reverse the loss of water-holding capacity by fish muscle proteins, chemical conditions such as the use of detergents or a highly alkaline pH have been suggested, but such conditions are generally unsuited to storing edible fish muscle.

It may be difficult to stop a dewatering operation at the proper time if one relies solely on analyses for moisture content. It is possible for one to develop a rapid, intuitive procedure with a bit of practice and follow-up analytical determinations. After several opportunities for practicing this art, I found that a sample of minced flesh should not form a puddle of water in the open palm of my hand, but this flesh should form a small puddle if I squeezed it gently. This subjective judgment had a surprisingly good correlation with the analytical data obtained from the minced blocks produced from this washed flesh.

Apart from the problem of how much to dewater the minced flesh after it leaves the separator, we are also investigating dewatering equipment which is feasible on a commercial scale. This equipment can be classified into three broad categories: screens, presses, and centrifuges.

On a pilot plant scale, we found that nylon mesh bags ("laundry bags") were a satisfactory type of screen for dewatering. After several empirical tests, we settled on placing about thirty pounds of wet minced flesh in a bag and hanging it on a support in a chill storage room (36° - 40°F). The bag was hung for one hour or less, depending on the time needed to dewater the flesh.

On a commercial scale, the use of nylon mesh bags can introduce problems such as slow throughput rate, high space requirements, and laundry expenses. With the cooperation of commercial processors, we are testing a Sweco vibrating screen for dewatering minced flesh. Several options are available with this equipment. Some of these options affect the throughput rate as well as the amount of dewatering of the washed minced flesh. For example, larger perforations in a screen increase throughput rate (partially because more "fines" escape with the liquid), and a larger diameter screen allows more time for dewatering the flesh. At present, we are using a single No. 20 screen (opening 840 microns, 0.0331 inch) five feet in diameter in a Sweco unit. This may not be the best combination for all applications, and for example, we are contemplating the use of a second Sweco unit to recover the "fines" that pass through the No. 20 screen with the water.

Presses are commercially available in a wide variety of capacities and pressures which can be applied for dewatering. We have used a simple cider press on a pilot-plant scale with essentially the same results as obtained by hanging a nylon mesh bag of minced flesh to dewater it. We are still looking for a press with a commercially feasible throughput and with quite low applied pressures.

Centrifuges are also available in a wide variety of equipment. Our initial experiments in dewatering minced flesh were based on a domestic type washing machine on a spin-dry cycle. The capacity of this batch centrifuge was obviously too small for commercial use, but we gained some useful data using it. Originally, it was capable of generating a centrifugal force of about 70 pounds per pound of flesh. This force tended to overdry the minced flesh so we geared it down to provide a centrifugal force of about 30 pounds per pound of flesh. This lower force was an improvement, but minced blocks made from this dewatered flesh had no drip at all.

On a commercial scale, centrifuges offer advantages of complete recovery of solids (including "fines") and continuous operation. We have used a DeLaval solid bowl centrifuge to dewater minced fish after it had been put through a strainer as well as the separator. By using centrifugal forces of 100 to 500 pounds per pound of flesh, drip was reduced from 8 percent to 3 percent even though the moisture content of these dewatered "fines" was 85 percent.

Flesh Separation by Straining

It is possible to prepare minced blocks from dewatered flesh that has not been put through a strainer. The texture of such blocks is at least equal to to the texture of minced blocks prepared from V-cuts. However, these blocks may not have a uniform appearance. They may have a few blood clots (not soluble in water), small pieces of skin or belly membranes. This non-uniformity in appearance may be disadvantageous in preparing fish sticks

from such blocks. Occasionally, a few small bone chips may be found in these blocks; and if found in a fish stick, these chips are not desirable.

To improve uniformity of appearance and freedom from bone chips, we have been putting the dewatered flesh through a Bibun strainer before making minced blocks. This machine uses an auger or "wiper" blade to place the incoming material against a perforated cylindrical screen. A conical tube is used at the far end of the screen to create a slight back pressure which helps squeeze the flesh through the holes of the screen. Bone chips or skin pieces pass through the conical tube along with some of the flesh. This "waste" can be put into a second strainer to increase the yield of flesh if desired.

The perforated cylindrical screen can be fabricated with a variety of different sized holes. We have used screens with holes between 1 and 3 mm diameter. Choosing a size for a particular application involves three considerations: desired size of flesh particles, freedom from skin pieces, and yield of flesh. With a larger hole, the flesh is not minced as thoroughly, but there is a possibility that some small pieces of skin may be forced through the holes. These pieces would give the flesh a non-uniform appearance. This possibility can be avoided by using a very low back pressure in operating the strainer and, if desired, by using a second strainer to separate minced flesh from the "waste" mixture of flesh and skin pieces discharged by the first strainer. On the other hand, using a screen with a smaller hole enables one to use a wider range of back pressures to increase the yield of flesh from a single strainer although this flesh is more thoroughly minced.

Making Blocks

Usually, we have frozen the minced flesh to preserve it. Our techniques were similar to commercial methods for freezing fillets into blocks. The minced flesh was weighed into either a 13½ pound or a 16½ pound waxed chipboard carton, frozen in a plate freezer, then stored at 0°F. We have not used flexible films to inhibit desiccation or oxidative deterioration during storage. Such overwraps have been used successfully to preserve a variety of frozen foods, in general, and to preserve surimi, in particular, by the Japanese industry. However, such overwraps are not common in our regular block industry, and their effect on the storage life of minced blocks has not been determined.

We have not determined the effect of specific compounds on the frozen storage life of minced blocks. In the Japanese method of making surimi, the washing step is designed to remove components which, if left in the minced flesh, can accelerate deterioration in its quality during storage (Tanikawa, 1971). The Japanese method also includes adding salt, sugar, condensed phosphates, or other additives to inhibit protein denaturation (loss of water holding capacity) in the surimi during storage (Tanikawa, 1971). These additives and antioxidants have also been used for storing minced black rockfish blocks to be made into fish sticks (Teeny and Miyauchi, 1972). Unlike most of the species we have used, black rockfish itself is notorious for poor frozen storage life due to lipid oxidation. Our limited experience suggests that, without additives, the useful frozen storage life of minced blocks can be extended by improving the time, temperature, and sanitary conditions of making these blocks, as well as the frozen storage conditions.

EVALUATION OF MINCED FISH BLOCKS

The quality of our minced blocks was evaluated by two organizations, the NMFS Inspection Service and a private consulting laboratory. Both evaluations were made in Gloucester, Massachusetts, on a frozen sample that we provided. Both organizations used the criteria given in Figure 5. Descriptive analyses were based on a 4-point scale (Excellent, Good, Fair, Unacceptable), and numerical analyses were based on standard AOAC methods.

Appearance and Color

Washing the minced flesh did improve the appearance of the minced blocks. The color of these blocks was described as reasonably off-white rather than snow-white. Clotted blood was not removed by the washing treatment, but the strainer treatment broke up these clots and diffused their color into the rest of the flesh. Some variation in color results from the choice of species or form of raw material from which the minced flesh is obtained. We have found that a slight pink color (the color of very dilute normal blood) in a minced block has been synonymous with good odor, flavor, and low total plate counts. In contrast, minced blocks which have a brownish tint (the color of dilute oxidized blood) may have developed a rancid, bitter flavor and/or a higher total plate count.

Odor and Flavor

The majority of the samples received a rating of good or fair by both inspection agencies. Those samples receiving the higher ratings were described as "bland flavor" and having "less odor."

Texture

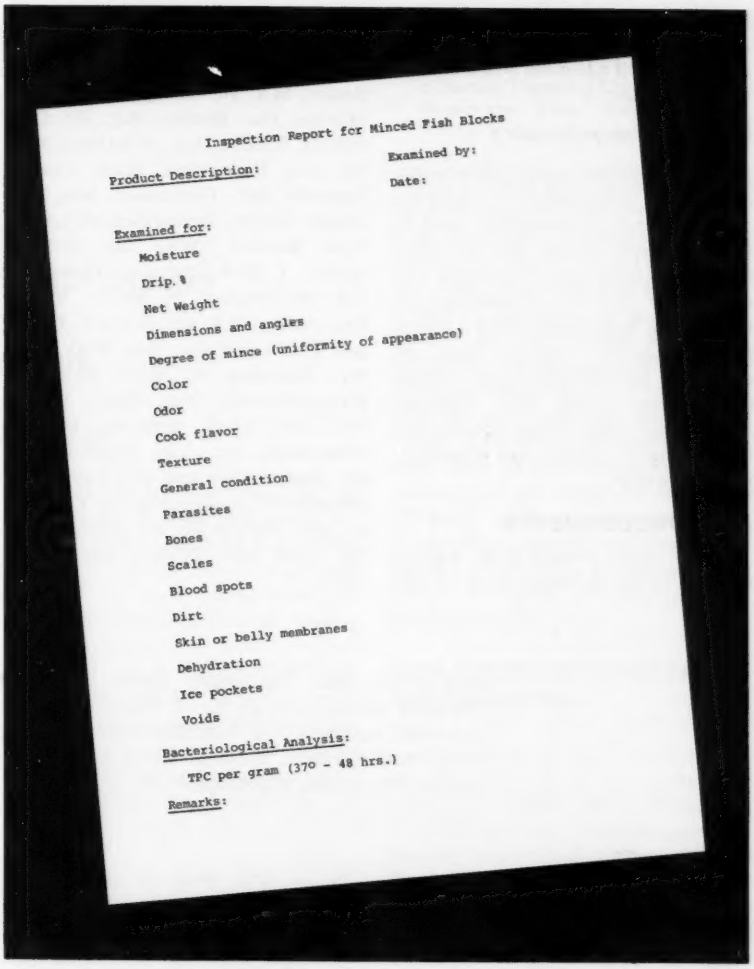
Comments were made on the texture or "mouth feel" of these minced block samples. These comments were made more frequently on the blocks which had the better ratings for color, odor, and flavor. They included adjectives such as "rubbery" or "tacky." It is not clear whether these adjectives were based on subjective comparison with a typical regular (fillet) block or with a typical minced cod block made from V-cuts. Although textural evaluations

tend to be more subjective than taste evaluations, it appears that further R&D work is appropriate to make the textural qualities of minced blocks more acceptable to American consumers.

Moisture and Drip

The moisture content of minced fish blocks prepared from washed flesh has been in the order of 75-85 percent. From the results of our sensory data, we suspect that the flavor and texture of minced fish blocks might be improved if they have a moisture content in the order of 5-10 percent greater than the original fish muscle. Love (1970) has reviewed factors which affect the moisture content of fish muscle itself.

The drip content of the same blocks varied from 0 to 10 percent. Unlike moisture content, drip is a measure of protein quality or water-holding capacity. We have prepared good quality minced blocks with 80-85 percent moisture on several occasions; however, we do not have enough storage data to indicate the suitability of such moisture contents on prolonging the useful storage life of these minced blocks. Our limited experience in storing minced blocks does indicate that minced fish flesh has a greater water holding capacity than intact fish muscle initially, but the minced flesh can be dehydrated more easily by fluctuations in time-temperature storage conditions as well as moisture permeable packaging.



Inspection Report for Minced Fish Blocks

Product Description: Examined by:

Date:

Examined for:

- Moisture
- Drip, %
- Net Weight
- Dimensions and angles
- Degree of mince (uniformity of appearance)
- Color
- Odor
- Cook flavor
- Texture
- General condition
- Parasites
- Bones
- Scales
- Blood spots
- Dirt
- Skin or belly membranes
- Dehydration
- Ice pockets
- Voids

Bacteriological Analysis:

- TPC per gram (37° - 48 hrs.)

Remarks:

Figure 5.—Inspection report for minced fish blocks.

Bacteriological Analysis

The lowest total aerobic plate counts in our minced blocks were in the order of 10^3 to 10^4 per gram. These counts were highly dependent on the freshness of the raw material. They were influenced by the speed with which we processed this material. They were lowered only slightly by washing the minced flesh before freezing it. When we used freshwater species, coliform and coagulase positive staphlycoccus were also estimated. The results (MPN per gram) did not indicate excessive contamination.

Miscellaneous Materials

Under this heading are categorized such things as parasites, bones, scales, blood spots, dirt, membranes. True parasites such as codworms or Sphyrion buttons were not found, presumably because our raw materials did not contain them. Occasionally a curled piece of white belly membrane was found which superficially resembled a codworm. Bones were not found partly because we excluded bone chips less than ⅛-inch long from our definition of bone. Scales and dirt (foreign materials) were eliminated by separating handling of the raw material from handling of the minced flesh. Blood spots (clots), pieces of skin or belly membrane and bone chips were sometimes found in separated, but not strained, flesh due to the hole size of the separator's drum (3, 5, or 7 mm) and the tension of belt against drum. These pieces were removed by putting

the separated flesh through a strainer (1 mm holes in its screen) and avoiding excessive back pressures while operating the strainer.

Physical Characteristics

Physical characteristics (dimensions and angles, dehydration, ice pockets, voids) relate to the techniques used to form and freeze a block. Our method of forming minced blocks by hand was satisfactory, but the extrudability of this minced flesh suggests that a faster, more productive method could be developed for commercial use. Dehydration was hardly ever observed because our blocks were usually not stored long enough for this characteristic to develop.

ACKNOWLEDGMENTS

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MFR PAPER 999

A new method has been devised by NMFS to increase the survival of juvenile salmon.

Collection and Transportation System of Juvenile Salmonids Evaluated at Little Goose Dam

PARKER S. TREFETHEN and WESLEY J. EBEL

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BACKGROUND AND OBJECTIVES

Survival of juvenile salmon—as well as steelhead trout—in the Snake River has declined significantly in recent years owing mainly to gas bubble disease, a condition caused by supersaturation of the river with nitrogen and other dissolved gases from spilling of water at dams. Before Lower Monumental and Little Goose Dams were built, over 90 percent of the young salmon managed to survive their seaward migration down the lower Snake River.

The term "nitrogen supersaturation" has fallen into common use (largely through convenience) to describe a condition known as excessive total dissolved gas pressure. Because air is nearly four-fifths nitrogen, references to the gas supersaturation problem have invariably highlighted nitrogen, even though the sum of all gas pressures is actually involved. Most of the Columbia River (and a major portion of the lower Snake River) is now a series of impoundments, or dams. The long succession of pools no longer provides the circulation necessary for rapid release of dissolved gases. Virtually all of the Columbia River below the U.S.-Canadian border and many miles of the lower Snake River are seasonally supersaturated to varying degrees, depending on river flows and amount of spill discharges at the dams. "Gas bubble disease" in fish is similar to the "bends" in deepsea divers. Fish, however, can contract the disease merely by remaining in supersaturated surface waters. An example of gas bubbles in a young fish is shown in Figure 1.

Reservoirs, or pools, delay the migration of juveniles by prolonging their exposure to high concentrations of dissolved gases, predation, and other adverse conditions. Such losses over a period of years could severely deplete the runs of salmon in a river. To offset this, the NMFS Northwest Fisheries Center's Division of Coastal Zone and Estuarine Studies designed a collection system at Little Goose, the uppermost dam in the lower Snake River. The collected fish are transported nearly 350 miles downstream around hazardous reaches of the river and released in the Columbia River below Bonneville Dam (Figure 2). Development and tests of the collection and transportation system were endorsed by State fishery agencies and financed by the U.S. Army Corps of Engineers. The system is now in the third year of a 6-year program.

FISH PROTECTIVE SYSTEM AND FACILITIES

At Little Goose Dam the young fish are diverted from turbine intakes into intake gatewells by means of traveling screens (Figure 3). From the gatewells, the fish pass through a submerged orifice into a bypass pipe (Figure 4) and are routed around the dam to a collection area (Figure 5) below the powerhouse. At this point the fish are either released into the tailrace or transferred

Figure 1. — Gas bubbles beneath skin on head of young chinook salmon. When bubbles burst, infections may set in and kill the fish. Gas absorbed into blood stream will cause emboli, which can block circulatory system and cause death.

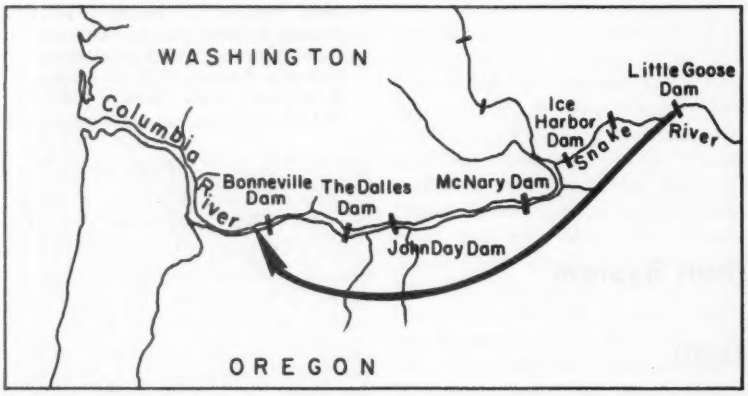
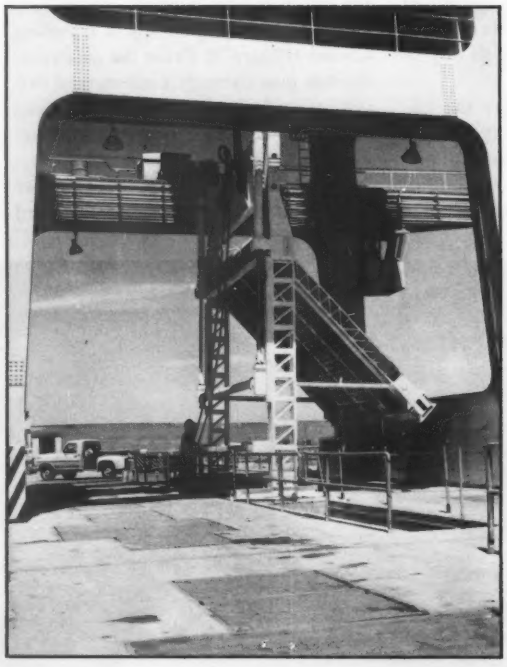


Figure 2.—Transportation route (heavy black arrow) from Little Goose Dam to Bonneville tailrace.

to a tank truck and transported downstream around hazardous areas.

Developmental studies by NMFS personnel at Ice Harbor Dam led to the design of the collection and transportation system. Tests had indicated that survival of truck-transported fish was about twice that of those migrating naturally downstream. Survival of fish transported during periods of heavy spills and high gas supersaturation was about three times that of non-transported fish.

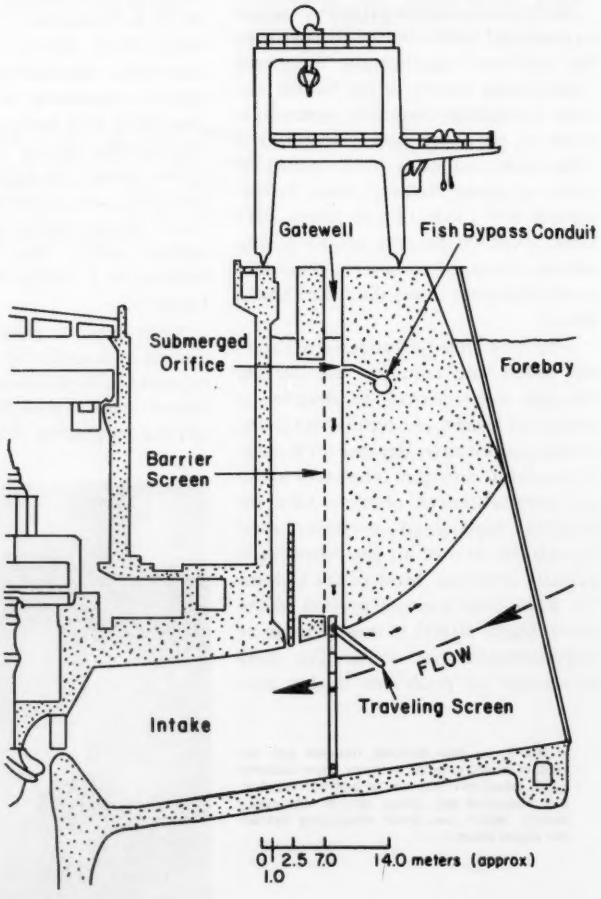
Figure 3.—Inclined traveling screen shown in operating position on deck of dam. Hydraulically operated arm is withdrawn to permit lowering of screen through gatewell slot.



EVALUATION OF THE SYSTEM

Returns of marked adult fish provide data on the effectiveness of the system. Juveniles are marked at the collection area (Figure 6) with a coded magnetic wire tag, a cryo-brand, and an adipose fin clip. Control groups are released

Figure 4.—Sectional view of powerhouse showing traveling screen in operating position within turbine intake.



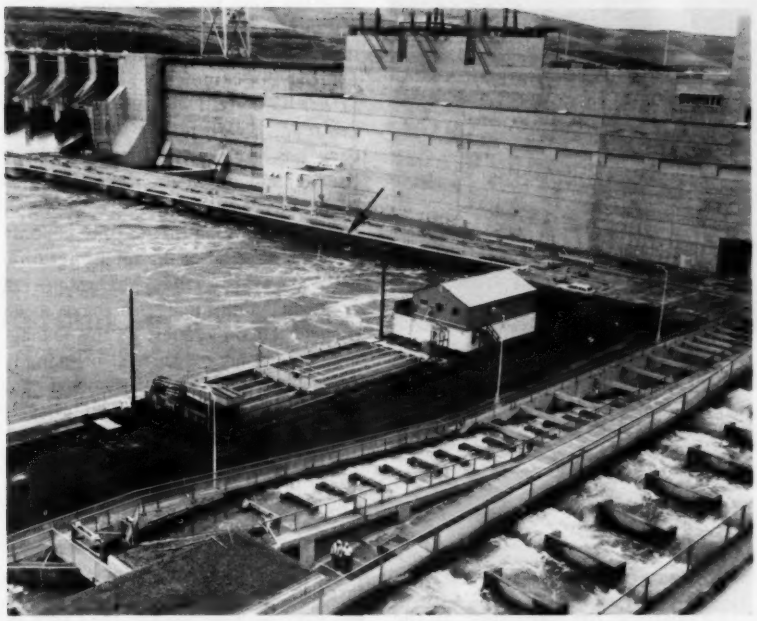


Figure 5. — Collection area into which fish are transferred through a pipe conduit (see arrow) from turbine intake gatewells. Here fish are graded by size and held in long raceways for inspection and marking.

above and below Little Goose Dam; test groups are transported by tank trucks and released below Bonneville Dam. Nearly 400,000 fish were handled in 1971 and about 900,000 in 1972.

When adult fish return to Little Goose Dam they pass through a special device in the fishway that detects those with a wire tag and diverts them into a holding area. Here the brand (Figure 7) is read and it is determined whether the fish had been transported and released downstream or had been released at the dam as a control. Identifiable fish are then released to continue their migration upstream. If the brand is not legible, the fish is held in a hatchery until spawned. The wire tag is then removed from the snout and the color code read for determination of the release site. Spawning ground surveys, conducted in cooperation with State fishery agencies, provide data on adults that pass Little Goose Dam undetected. Further data are obtained from recoveries in the commercial fishery in the lower Columbia River and from the sport fishery in the Snake and Columbia Rivers.

Returns in 1972 of early-maturing (1 year in the ocean, "jack") steelhead trout, released as juveniles in 1971 at Little Goose Dam (controls) and at Bonneville Dam (transported), are encouraging. Chinook salmon recovered this year have been too few for computation of benefit ratios due to transport, but preliminary estimates of benefit (based on recoveries of 327 fish) computed from trout returns indicate that survival of transported fish was 61 percent greater than that of nontransported fish. Should future returns of adult fish follow the same pattern as in past years at Ice Harbor Dam (confluence of Snake and Columbia Rivers), final estimates of increased survival of salmon and trout—attributable to transportation in 1971—should exceed 100 percent. This projection is predicted on evidence that transport/control ratios are higher for 2- and 3-ocean fish than for jacks.

Figure 6. — Interior of marking shed near collection area where young fish are branded and wire tagged in assembly line. The fish are pumped into holding tank from raceways, anesthetized, and diverted to fish marking stations. After processing, the fish are transferred by gravity flow through pipe into tank truck.

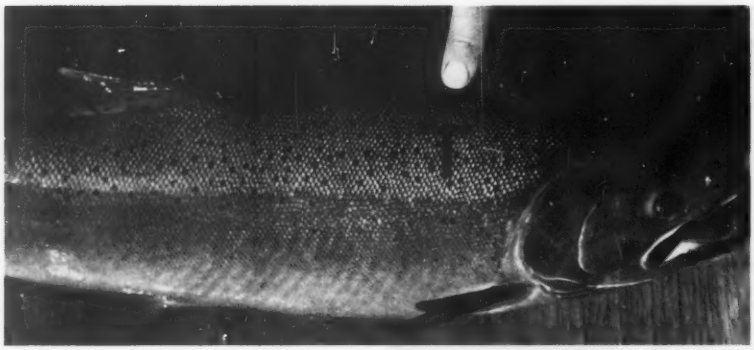


Figure 7.—Cryo-brand on adult steelhead trout. Fish had returned to Little Goose Dam after having been caught and branded at the dam during its juvenile stage and transported downstream below Bonneville Dam.

Fish losses during the collection and transport process appear mainly related to descaling and other physical injuries. To reduce losses during collection and transport, the staff is determining causes of injuries and stresses incurred by fish while they are being collected, marked, transported, or released. In areas where descaling occurred, their causes have been pinpointed and preventive steps are underway. Points of stress are identified through blood chemistry studies; so far there is little indication that increased stress seriously affects survival.

FUTURE PLANS

To increase the capability of the system for diverting fish from turbine intakes at Little Goose Dam, the Corps of Engineers is currently installing six additional traveling screens, completing the screening of the three turbines now operating at that project. With the increased screening capability, up to 90 percent of the migrants could be diverted from the river when no spilling occurs. In 1975, fish passage facilities similar to those at Little Goose Dam will commence operation at Lower Granite Dam about 45 miles upstream. Ultimate management decisions concerning the future extension and application of the transport concept must await the results of ongoing studies. For the present, only a minor fraction of the total migration is being used to evaluate the system. On occasion, additional fish have been transported on request of the managing State fishery agencies, principally during periods when dissolved gas concentrations in the river are at levels dangerous to fish.

The need to prevent losses of young fish will increase in the future as river flows are more controlled, spilling at dams decreases, and a greater proportion of the seaward migrants are forced through turbines. To prevent losses of fish from turbine passage, the Corps of Engineers proposes installation of screens in the intakes of a number of dams to bypass fish around each project. Implementation of these plans would again depend on the results of studies by NMFS to determine effectiveness of the traveling screens and bypass systems.

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MFR PAPER 1000

A unique approach to the problem of safely transporting juvenile fish by truck has been designed and tested.

Aircraft-Refueling Trailer Modified to Haul Salmon and Trout

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ABSTRACT

Two 5,000 gallon tanks from aircraft-refueling trailers were modified and equipped with life support systems to haul juvenile fish (seaward migrants) past various sections of the Snake and Columbia Rivers. The tanks and life support systems were evaluated from observations of fish mortality and water quality measurements recorded during hauls of a total of 1.4 million fish comprised of hatchery and wild stocks. Mortalities ranged from 0.05 to 1.33 percent. Analysis of water quality in the tanks indicated that the life support systems were suitable for hauling loads of up to 1.5 pounds of fish per gallon of water for 300-450 miles (5-10 hr duration).

INTRODUCTION

Anadromous salmon and trout that spawn in the Columbia and Snake Rivers (the Snake River is a large tributary of the Columbia) constitute a valuable marine resource off the west coast of the United States for both commercial and sport fishermen. In recent years, there have been substantial losses of the juvenile migrants directly attributed to problems associated with dams and reservoirs (Long and Krcma, 1969; Ebel, 1970) on the two rivers. As a result, the National Marine Fisheries Service has been conducting studies to determine whether a system of collection and transport of seaward migrants might be a possible solution for reducing the losses.

Implementation of such a system would require vehicles that can haul large numbers of live fish over long distances. Two surplus aircraft-refueling tanks with a capacity of 5,000 gallons were altered and fabricated with life support systems for use in these experiments.

This report describes the tank trucks (with the special emphasis on the life support systems used in the tanks) and presents a brief summary of the use of the trucks in 1972 to transport fish downstream.

Figure 1. — Truck and trailer used by NMFS to haul juvenile salmon and trout down the Snake and Columbia Rivers in 1972.

FISH TANKS AND LIFE SUPPORT SYSTEMS

The tanks that we used for hauling fish originally had been used to haul aircraft fuel. Pumps, gauges, and other equipment used in refueling aircraft were removed. The interiors were sandblasted, steam cleaned, epoxy painted, and checked for toxicity before life support systems were installed. The exterior of each tank was insulated with 3 inches of styrofoam.

Each tank was divided into two main compartments, the forward compartment having three splash baffles and the rear compartment having a single baffle. The combined capacity of the compartments was 5,000 gallons. However, part of the interior was needed for the overhead sprinkler system which reduced the hauling space to about 4,000 gallons, with 2,200 gallons in the front compartment and 1,800 in the rear compartment. A refrigeration unit, recirculating pump, and filter, in addition to liquid and compressed oxygen bottles, were installed on a platform at the rear of the trailer. The complete

unit was 35 feet long overall; the tank, 26 feet long (Figure 1).

A model R-1000D refrigeration system, made by Harris Thermal Transfer Products, Inc.,[1] was used for cooling and recirculating the water supply. The 120,000 BTU system can provide a maximum 10 degrees per hour pull-down and maintains a preset temperature within 1.8°F (±1°C). This model chiller was specifically designed to avoid clogging.

The primary recirculating pump, which was provided with the chiller, was capable of circulating 150 gallons of water per minute. Spray aeration from overhead nozzles and from jets near the bottom of the tank provided oxygen and also insured adequate water exchange in all areas of the tank. (See Figure 2 for diagram of recirculation and aeration system.) A 3 × 16 inch cylindrical standpipe covered with mesh screen was placed over each of the six intakes (to the refrigeration unit) which were evenly spaced in the bottom of the tank. These standpipes prevent dead fish from blocking the intake lines. Each of six intake ports was fitted with an orifice to provide even distribution of flow from all intake ports regardless of location from the main intake line. A standby pump with 150-gpm capacity was also provided for recirculation and aeration of water in case of failure of the refrigeration unit. The entire water supply could be circulated through the chiller and auxiliary pump in about 27 minutes.

A Model PF-100 sand filter, manufactured by the Pacific Manufacturing Company, was incorporated into the recirculating system to reduce the amount of foam, slime, feces, scales, and regurgitated food in the tank. The device could be adjusted to control the amount of water passing through it; the volume of flow was determined by means of a flowmeter on the output side of the filter. Maximum filtering capacity of the system was 100 gallons per minute, and its working pressure was 50 pounds. The filter could be cleaned by flushing about 70 gallons of water back through the output side of the device.

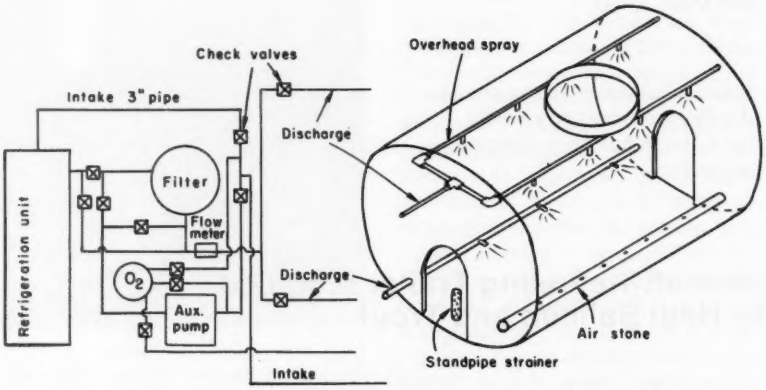

Figure 2. — Diagrammatic view showing life support system in one of the six sections of the tank truck.

Oxygen was discharged into the tank through six carborundum stones (2 inches in diameter and from 24 to 54 inches long depending on location in tank) or through the recirculating pump intake or both. One liquid oxygen bottle (LC-3 size) served as the main supply. The bottle was equipped with an expansion chamber which allowed a continuous supply of gas at a pressure of 40 psi. Oxygen flow was controlled by a medical type flowmeter which was accurate to within ±0.13 gallon (±0.5 liter) gas per minute. One cylinder of oxygen of 3,000 pound-pressure was also carried for emergencies.

Temperature, oxygen input, recirculating pump pressure, and oil pressure of the refrigeration unit were monitored from the cab of the truck.

FISH HAULING OPERATIONS IN 1972

About 1.4 million juvenile salmon and steelhead trout, *Salmo gairdneri*, were hauled. The majority were smolts — some were taken directly from hatcheries and others were captured during their seaward migration.

Fish Hauled from Hatcheries

About 820,000 of the fish hauled were taken from hatcheries. Approximately 320,000 of the hatchery fish were transported a rather short distance — 30 miles — to test the truck systems, but the remaining 500,000 were transported a considerable distance — 450 miles — down the Columbia and Snake Rivers.

Coho salmon, *Oncorhynchus kisutch*, that were hauled 30 miles for test purposes were transported from Ringold Hatchery to holding pens near Pasco, Wash., 8-10 February 1972. Load densities varied from 0.5 to 1.5 lb of fish per gallon of water (Table 1). Mortality was nil and oxygen concentrations remained high. Obviously, the transport system was never loaded to capacity. During one trip we wished to examine the efficiency of the aeration stones for oxygenating the water. All other life support systems were inactivated. This transport was made with a light load of 0.5 lb of fish per gallon of water. Dissolved oxygen at destination after a 60-minute haul was reduced to a

[1] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

Table 1.—Transport data from loads of various densities of fingerling coho salmon (20/lb) hauled from Ringold Hatchery to Pasco, Wash., February 1972.

Load density (lbs/gal)	Temperature (°F)		Concentration of oxygen in tank (PPM)			Haul time (min)	Recirculating system operating	Oxygen fed, metered, to tank (LPM)		Mortality (%)
	Start of loading	Destination	Start of loading	Start of transport	Destination			To stones	To recirculating pump intake	
0.5	45	46	11.1	—	6.4	60	No[1]	7.0	No	0
0.75	39	39	11.9	—	—	60	Yes	3.0	3.0	0
0.83	41	42	14.7	7.9	—	90	Yes	3.5	1.5	0
0.87	48	46	13.4	13.4	12.1	100	Yes	3.0	3.5	0
0.90	44	45	16.8	11.4	10.8	90	Yes	3.5	1.5	0
1.0	48	48	13.3	9.6	10.0	60	Yes	3.0	3.5	0
1.1	41	43	12.6	10.0	7.4	120	Yes	3.0	1.5	0
1.5	39	39	14.5	15.3	—	60	Yes	5.0	3.25	0

[1] Recirculating system operational during loading.

minimum tolerable level of 6.4 ppm. Evidence accumulated from these series of hauls indicated that injecting oxygen into the intake line of the pump was more efficient than injecting through stones to maintain an acceptable oxygen concentration.

The hauls of 450 miles were made in April from Rapid River Hatchery, Idaho, to Bonneville Dam, which took from 10 to 12 hours. Spring chinook salmon, *O. tshawytscha*, in smolting condition were hauled in these tests. Basic water quality data such as temperature and oxygen concentrations were recorded at the destination of each load along with mortalities that occurred during the hauling period.

Mortality of hatchery fish transported 30 and 450 miles was always under 0.05 percent. Thus from these data, we considered the tank more than adequate for hauling hatchery smolts (the above fish were hauled at densities of 1 lb of salmon per gallon of water over the longer distance and up to 1.5 lb per gallon for the shorter distance). The tanks were never loaded to capacity when all life support systems were operational; further testing is needed to determine the maximum carrying capacities for hatchery stocks.

Transport of Fish Captured During Migration

In the spring, a total of about 600,000 chinook salmon and steelhead trout were collected at Little Goose Dam and transported to Bonneville Dam, a distance of about 350 road miles. Water in the tanks was analyzed at Bonneville Dam for concentrations of ammonia, nitrogen, dissolved oxygen, carbon dioxide, pH, and total alkalinity. Basic data recorded during the hauls when hatchery-reared fish were transported were also recorded when smolts captured during migration were transported. These data provided a basis for judging water quality control in our system.

Of the above fish, 260,000 were used in a study to obtain information on water quality and mortality of fish associated with "high density" loads (Table 2). The water quality data from the above loads indicate that oxygen was more than adequate. The pH values were at a level where interaction between pH and toxicity of ammonia did not become a critical factor influencing mortality. The average mortality of the transported fish was 1.33 percent. In addition to these high density loads, 350,000 other smolts were hauled in 33 trips to the Bonneville release site. Average mortality in these loads was 0.55 percent. All loads from Little Goose Dam were hauled in turbid, Snake River water, which made filtration necessary.

Although higher mortalities occurred with the captured migrating fish than with the fish taken directly from hatcheries, we believe that the tank and life support systems are nearly optimal for the former group of smolts. The higher mortality of captured migrating fish did not appear to be related to a subtle stress factor associated with the response of this group of fish to hauling. Rather, it appeared to be directly associated with injuries incurred at the time of capture at Little Goose Dam (examination of dead smolts at the release site revealed that 90 percent had some descaling or other injury that probably occurred prior to hauling).

Table 2.—Transport data from six loads of chinook salmon and steelhead trout (mixed) hauled from Little Goose Dam to Bonneville Dam, 1972.

Date	No. fish in load	Pounds per gal.	Mortality		Water quality from transport tank at dest.				
			Number	Percent	O_2	CO_2	NH_3	pH	Total alk.
5-6	33,000	0.84	350	1.06	9.8	17.0	4.0	7.2	84
5-8	43,076	1.10	243	0.56	9.8	25.0	7.0	6.8	74
5-9	43,313	0.95	400	0.92	10.38	26.0	7.0	6.8	72
5-10	40,440	1.10	1,300	3.21	11.96	29.0	8.0	6.8	73
5-11	44,118	[1]1.10	696	1.56	18.15	15.0	6.2	6.8	62
5-12	39,146	[2]1.05	275	0.70	16.05	14.5	3.0	6.8	60

[1] 1.5 pounds per gallon in rear compartment (1.1 overall load density).
[2] 1.2 pounds per gallon in front compartment (1.05 overall load density).

Table 3. — Number of fish and quantity of water needed at start of haul for load density of 0.25 lb of fish per gallon of water[1] (number of fish and quantity of water, of course, will vary with average body size of fish).

Size of fish (fish/lb)	Quantity of water in tank (gallons)										
	1,000	1,100	1,200	1,300	1,400	1,500	2,000	2,500	3,000	3,500	4,000
1	250	275	300	325	350	375	500	625	750	875	1,000
2	500	550	600	650	700	750	1,000	1,250	1,500	1,750	2,000
3	750	825	900	975	1,050	1,125	1,500	1,875	2,250	2,625	3,000
4	1,000	1,100	1,200	1,300	1,400	1,500	2,000	2,500	3,000	3,500	4,000
5	1,250	1,375	1,500	1,625	1,750	1,875	2,500	3,125	3,750	4,375	5,000
6	1,500	1,650	1,800	1,950	2,100	2,250	3,000	3,750	4,500	5,250	6,000
7	1,750	1,925	2,100	2,275	2,450	2,625	3,500	4,375	5,250	6,125	7,000
8	2,000	2,200	2,400	2,600	2,800	3,000	4,000	5,000	6,000	7,000	8,000
9	2,250	2,475	2,700	2,925	3,150	3,375	4,500	5,625	6,750	7,875	9,000
10	2,500	2,750	3,000	3,250	3,500	3,750	5,000	6,250	7,500	8,750	10,000
11	2,750	3,025	3,300	3,575	3,850	4,125	5,500	6,875	8,250	9,625	11,000
12	3,000	3,300	3,600	3,900	4,200	4,500	6,000	7,500	9,000	10,500	12,000
13	3,250	3,575	3,900	4,225	4,550	4,875	6,500	8,125	9,750	11,375	13,000
14	3,500	3,850	4,200	4,550	4,900	5,250	7,000	8,750	10,500	12,250	14,000
15	3,750	4,125	4,500	4,875	5,250	5,625	7,500	9,375	11,250	13,125	15,000
16	4,000	4,400	4,800	5,200	5,600	6,000	8,000	10,000	12,000	14,000	16,000
17	4,250	4,675	5,100	5,525	5,950	6,375	8,500	10,625	12,750	14,875	17,000
18	4,500	4,950	5,400	5,850	6,300	6,750	9,000	11,250	13,500	15,730	18,000
19	4,750	5,225	5,700	6,175	6,650	7,125	9,500	11,875	14,250	16,625	19,000
20	5,000	5,500	6,000	6,500	7,000	7,500	10,000	12,500	15,000	17,500	20,000

[1] The number of fish needed for other load densities can be easily obtained by applying this table. For example, a load density of 0.50 lb of fish per gallon of water would require twice as many fish as shown above; a load density of 1.00 lb would require four times as many fish.

The tank safely held chinook salmon and steelhead trout in densities up to 1.5 lb of fish per gallon of water. Based upon our observations, we believe 1.5 lb per gallon may be near capacity for the unit when hauling smolts that had been captured during their seaward migration.

To simplify loading operations at Little Goose Dam, we developed a table that was used to determine the number of fish to be loaded to attain any desired density (Table 3). Although the table was of particular value to us, it could also be applied to any hatchery release operation where tanks of 1,000-4,000 gallon capacity are used.

ACKNOWLEDGMENTS

Special thanks are due Robert Manis and Wallace Iceberg, both of the National Marine Fisheries Service, for many of their innovative ideas utilized in converting the aircraft refueling tanks into fish hauling tanks.

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Robert W. Schoning Named National Marine Fisheries Service Director

On July 12, Secretary of Commerce Frederick B. Dent announced the appointment of Robert W. Schoning as Director of the National Marine Fisheries Service.

Mr. Schoning has served as Deputy Director of NMFS, an agency of the Commerce Department's National Oceanic and Atmospheric Administration, since September 1971.

"I am delighted that Mr. Schoning has accepted this position," said Secretary Dent. "His extensive experience, particularly at the state level, has given him a thorough understanding of, and interest in, the many fishery problems and opportunities common to our states, and I know he will approach those problems vigorously.

"His fine work, at state and national levels, with the commercial fishing industry, the nation's sports fishery, the conservation and scientific communities, have provided a background of rare qualification for this important and difficult post. I know that under his leadership, the Fisheries Service will give outstanding service to the nation."

Mr. Schoning succeeds Philip M. Roedel, who was recently appointed NOAA's Coordinator of Marine Recreation Programs, with responsibilities across the entire agency.

The National Marine Fisheries Service seeks to discover, describe, develop, and conserve the living resources of the sea, especially as these affect the American economy and diet. The Fisheries Service conducts biological research on economically important species, analyzes economic aspects of fisheries operations and rates, develops methods for improving catches and, in cooperation with the U.S. Department of State, is active in international fisheries affairs.

With the U.S. Coast Guard, the Service conducts enforcement and surveillance operations on the high seas and in territorial waters. It also studies game fish and other marine and estuarine organisms, and investigates the effects on game fish of thermal and chemical pollution.

New Director Has State, Federal Experience

A well-known fishery scientist and administrator, Robert W. Schoning served as State Fisheries Director, Oregon Fish Commission, 1960-1971, following two years as Assistant State Fisheries Director. Prior to that, he was Director of Research for the Oregon Fish Commission.

Schoning

Born in Seattle, Washington, in 1923, Mr. Schoning holds a bachelor of science degree in fisheries from the University of Washington and has done postgraduate work in fisheries and mathematics.

Mr. Schoning saw active service in the Marine Corps in both World War II and the Korean conflict and is currently a colonel in the U.S. Marine Corps Reserve.

He is known for his writings on salmon and other fishery matters of the Pacific Northwest, and holds membership in a number of professional and conservation organizations including the American Institute Fisheries Research Biologists, American Fisheries Society, Pacific Fisheries Biologists, and Izaak Walton League of America.

Mr. Schoning and his wife, Barbara, live in Falls Church, Va. They have four children: Randall, James, Kerry, and Kip.

U.S.-Canada Fishing Agreement Extended

Delegations of Canada and the United States met at Ottawa from May 23 to May 26 to review the provisions of the Agreement of April 1970, on fishing within reciprocal fishing areas off the coasts of the two countries and to consider future arrangements.

The two delegations agreed to recommend to Governments that the 1970 Agreement be extended for one year with a number of modifications. A major amendment related to the provisions concerning fishing for Pacific salmon within the reciprocal fishing areas off Vancouver Island and off the State of Washington. It was agreed that such salmon fishing privileges for Canada, off Washington, would be reduced to the area between Carroll Island (approximately 48° N. latitude) and Cape Flattery, and the U.S. salmon fishing privileges off Vancouver Island for commercial troll vessels would be limited to a small area near the entrance to the Strait of Juan de Fuca. This will not affect continued fishing by U.S. recreational vessels subject to Canadian licensing and other regulations.

Agreement was also reached on arrangements to coordinate salmon fishing regulations of the two countries in

the Strait of Juan de Fuca and northern Puget Sound. In addition, arrangements were made to coordinate weekly fishing periods on the Fraser River and at Point Roberts during the chinook season in the spring and the chum salmon season in the fall.

With respect to the Pacific coast it was also agreed to include in the Agreement provision for limited fisheries for black cod in the reciprocal areas of both countries.

On the Atlantic coast the modifications included provisions governing a limited Canadian fishery for tuna within the U.S. reciprocal area and regulation of the larger U.S. trawlers in areas off Canada where similar Canadian trawlers are prohibited from operating. Provisions regarding herring will continue relatively unchanged.

Source: U.S. Department of Commerce News, 73-144.

Coho Introduced Into Barren Alaska Waters

By planting tiny coho salmon called "fry" in unused Alaskan lakes and streams, fisheries scientists of the Commerce Department's National Oceanic and Atmospheric Administration plan to increase Pacific salmon returns there. Similar programs have been used by Federal and State fisheries scientists in Oregon and Washington for several years.

On Baranof Island alone, high barrier falls prevent adult salmon from reaching thousands of acres of productive streams and lakes for spawning. Such waterfalls generally do not hinder downstream migration of young salmon, however. Other parts of Alaska have an abundance of similarly obstructed waters, many of which could be used for rearing newly hatched salmon to the migrant or "smolt" stage, thus increasing adult salmon returns. "Smolts" are juvenile salmon about six inches long that are physiologically ready to migrate from fresh water to the sea.

The plan is geared to making use of unused waters by annual plantings of fry, rather than attempting to establish self-perpetuating salmon runs, according to National Marine Fisheries Service Alaska Regional Director Harry L. Rietze. With modern techniques, salmon fry are relatively inexpensive to produce in established hatcheries. The major cost—feeding and rearing the fish to the smolt stage—would be taken care of naturally in the lakes and ponds now barred to salmon production.

In a pilot study at the Little Port Walter Field Station on Baranof Island in Southeastern Alaska, 12,000 coho salmon fry were stocked in a four-acre lake. They grew rapidly, and 6,800 migrated to sea as one- and two-year-old smolts. After spending about 16-18 months in the rich ocean pastures, 724 adults (more than a 10 percent return) came back to the outlet stream. Possibly an equal number of adult migrating coho salmon were caught by sport and commercial fishermen. Studies are continuing, including the experimental planting of an additional 132,000 coho fry last summer.

Encouraged by the results, a large-scale interagency demonstration project of stocking salmon fry in unused waters in southeastern Alaska is now planned by the NMFS, the Alaska Department of Fish and Game and U.S. Forest Service biologists. Once stocking levels for different types of lake, pond, and stream habitats are established, fishery scientists foresee stocking the fry from centralized hatcheries from airplanes or helicopters in the larger lakes and ponds.

Currently the fry come from brood stocks of coho salmon whose eggs are incubated and hatched in gravel "incubator" boxes at Little Port Walter. The fry are then carried by backpack to the isolated areas where they grow to migrating size. As adult spawning salmon attempt to return to inaccessible stream or lake areas, the entire run would be available for sport and commercial fishermen.

U.S., Mexico Examine New Fisheries Rules

The fourth of a series of U.S.-Mexican talks on the implications of a new Mexican fisheries law for certain groups of California fishermen was held in Mexico City in January. The other meetings on the matter took place in 1972 in Washington, July 12-13, in Mexico City, November 14-16, and in San Diego on December 20.

The fisheries law giving rise to these bilateral discussions became effective June 13, 1972. The law seriously concerned a number of southern California fishermen, who had for many years been fishing inside Mexican waters under a "via la pesca" licensing system. The principal reason for their concern was that the article of the Mexican law dealing with foreign fishing could have, in their opinion, made it very difficult for many U.S. vessels to continue to operate in Mexican waters. The provision creating the most difficulty was one requiring vessels operating under Mexican licenses to employ crews comprising at least 50 percent Mexican nationals, which could have caused certain small vessels severe economic hardship and created serious problems for other slightly larger ones which presently operate in Mexican waters.

Other provisions of the new fisheries law could also have created difficulties, such as those relating to cash deposits for licenses and penalties for violations.

Another Mexican law, a decree by the Government in December of 1971, also fundamentally altered the terms under which many U.S. Pacific Coast fishermen for years obtained licenses. In essence, these new regulations terminated the long established schedule outlining periods of license validity for various size classes of vessels and substituted a revised set of vessel size classes and corresponding periods of

validity, thereby making the practical application of the new licensing system most difficult, in fact, almost useless for certain sizes of vessels.

These problems were pointed out to Mexican fishery officials as early as July 1972, and after a series of discussions the following understanding was reached in January 1973: 1) the 50-percent Mexican manning requirement would be applied on an overall fleet basis, with certain exemptions which will, in effect, require no changes in present U.S. practices; and 2) on periods of validity of "via la pesca" permits, vessels could have permits extended on a pro rata basis up to 5 or 10 days, depending on size.

The Mexicans confirmed that: 1) cash deposits under the licensing system can be made on a group basis in San Pedro and San Diego (as has been done in the past); 2) it would exercise discretion in applying the confiscation provision for violations of the fisheries law; and 3) both sides understand that "similar pay and benefits" provision of the law means equal pay for equal work.

Regarding the law's most difficult provision, calling for at least 50 percent Mexicans in crews of U.S. vessels operating under Mexican license, it was agreed that in calculating the percentage of Mexicans aboard U.S. vessels, a global or fleet figure would be used, rather than the requirement being applied to each individual vessel. Vessels with three men or less on board would not be counted, nor would captains and engineers. Further meetings are scheduled to review the practical and administrative difficulties that may arise.

U.S. Purchases Of ROK Fish Products Rise

South Korea exported US$36,387,000 worth of fishery products to the United States in 1972 ($29.3 million in 1971) (Table 1). Most of this was tuna (valued at $31 million) and canned oysters ($3.5 million). The value of ROK's fishery exports to the U.S. increased by 33 percent over similar exports in 1971, reports the NMFS International Activities Staff.

Table 1. — Value of South Korea's fishery exports to the United States, 1971-72

Commodity	1971	1972
	Value US$1,000	
Fish:		
Fresh	26,893	31,287
Frozen	367	411
Canned	1,309	3,596
Pickled & salted	19	18
Seaweeds:		
Laver	220	137
Agar-agar	16	24
Other	21	43
Other:		
Fish nets	430	796
Other	57	175
Total	29,332	36,387

South Korea's total world fishery exports were valued at $152,564,000 in 1972 ($114,981,000 in 1971) with the most valuable commodities being: Tuna ($68 million), "other" live and fresh fish ($27 million), frozen seafoods ($12 million), fresh squid ($11 million), fish nets ($10 million) and canned seafoods ($5 million).

Source: U.S. Embassy, Seoul, February 8, 1973.

Japanese, Irish Enter Joint Fishery Venture

The Japanese Nichiro Fisheries Company and the Irish Government have begun to jointly develop new fishing grounds off Ireland, according to a report received by the National Marine Fisheries Service. After one year of experimental fishing, Nichiro and the Irish Government will form a joint venture company for full-scale commercial operations, including the processing and sales of the fish catches.

During the first year of exploratory fishing, one 500-gross-ton Japanese trawler will be operated out of County Cork, in southern Ireland, with a catch target of 2,000 tons of fish, including squid, cuttlefish, flatfish and herring. Present plan calls for increasing the number of trawlers to five in five years for a total catch of 10,000 tons annually. Some of the fish will be filleted, frozen or packaged for export to Japan and others will be sold to the Common Market countries.

In this venture, Nichiro is tied up with the Irish Government's Industrial Development Board and the Marine Fisheries Bureau. The Japanese firm plans to invest approximately 1,500 million yen (about US$5.66 million) in this undertaking within the next five years and will also cooperate in the operation of cold storage and processing plants.

Norway Posts Second Best Fisheries Year

The Norwegian fisheries had its second best year in 1972 with landings of 2,852,000 metric tons, according to Salvatore Di Palma, Regional Fisheries Attache for Europe at the U.S. Embassy, Copenhagen, Denmark. The value of the exports reached a record $375.9 million with higher prices for cod and saithe products contributing to the increase.

LIMITED ENTRY

Failure to join the European Community (EC or Common Market) will affect only about 12 to 15 percent of the Norwegian exports of fishery products, even without any expected concessions. In June 1972, the government was given authority to limit entry of vessels into the fisheries. Norway agreed to international limits on fishing for herring and salmon. Despite a strong effort to secure wider fishing limits than the present 12 nautical miles, the government decided in 1972 to await the outcome of the United Nations Law of the Sea Conference. Mr. Salvatore's findings are outlined in the NMFS Foreign Fisheries Leaflet No. 73-15, *Marine Fisheries of Norway, 1972.*

LESS FISHERMEN

The number of Norwegians involved in commercial fishing continues to decline, according to Di Palma.

From 61,000 commercial fishermen in 1960, the number fell to 35,000 in 1971. Of these, 25,000 were full-time or main-occupation fishermen and the rest were only part-time fishermen.

Predictions are that the total number will drop to 15,000 by 1980, with the ratio of full-time fishermen increasing. The catch per fisherman has risen over the past years and better gear and improved fishing techniques are cited as the reasons.

Most Norwegian commercial fishermen are said to earn more than most skilled and unskilled land workers in Norway. Yet, there is a declining interest among the young to become fishermen and, as a result, the average age of fishermen has increased. To encourage the type of young men wanted for the fishing industry, training is being improved, earlier retirement (at 62 years of age) has been proposed, and even special tax advantages are being considered.

Japanese Hike Shrimp Purchases

Japan imported 88,120,260 kilograms (193,864,572 pounds) of frozen shrimp, valued at US$291.9 million, in 1972, according to William B. Folson in NMFS Foreign Fisheries Leaflet No. 73-11. This record figure represents a 12 percent increase in quantity and a 36 percent increase in value over 1971 imports. Table 1 shows the phenomenal growth in Japan's shrimp imports since 1960.

Table 1. — Japan's frozen shrimp imports, 1960-72

Year	Value	Quantity
	US$1 million	1,000 metric tons
1972	291.9	88.1[1]
1971	214.0	78.8
1970	137.0	57.1
1969	121.7	48.8
1968	78.0	35.2
1967	79.7	44.4
1966	60.0	36.1
1965	35.9	21.0
1964	31.4	17.0
1963	23.5	11.7
1962	6.2	3.6
1961	6.9	4.1
1960	6.6	--

[1] Quantity expressed in heads-off weight.

This record growth was surprising in view of the reported sluggishness of the Japanese shrimp market during most of 1972. Shrimp purchases made by speculators in late 1971 resulted in very heavy accumulations between January and September 1972. Prices were also reported generally depressed for much of the year, and many Japanese importers appeared concerned that increased imports would further dampen the market; yet imports during most of 1972 were higher than they had been in 1971.

The most significant change in Japan's trade pattern in 1972 was that Indonesia replaced India as Japan's major source of frozen shrimp (Table 2). Although imports from India increased by 3,008 metric tons (a 32 percent increase), this was surpassed by a 5,599-ton (68 percent) increase in imports from Indonesia. In the past two years imports from Indonesia, where the Japanese are heavily investing in joint shrimp ventures, have increased tremendously.

Table 2. — Japan's 10 leading shrimp suppliers, 1971-72

Country	Quantity		Value	
	1972	1971	1972	1971
	Metric tons		US$1 million	
Indonesia	13,823	8,224	46.1	21.3
India	12,811	9,703	39.9	23.6
Thailand	7,506	7,080	24.2	17.9
Malaya, West	5,840	5,169	13.5	9.8
Mexico	5,406	6,520	22.3	21.3
Taiwan	4,555	4,464	11.8	9.9
Australia	4,095	3,974	19.2	14.1
Hong Kong	3,539	3,951	15.3	14.1
Mainland China	3,519	5,283	15.4	17.6
Pakistan	2,606	3,557	9.0	8.0

Imports from Mexico, Taiwan, Hong Kong, the People's Republic of China, and Pakistan, which are major suppliers, decreased. Imports from South Vietnam showed the greatest increase, almost 12-fold. In 1972, Japan concluded an agreement with Mexico to have shrimp shipped directly to Japan, thereby eliminating United States middlemen. This agreement, which provided for the purchase of about 7,000 metric tons of shrimp, apparently has not proven as successful as anticipated.

ROK, Taiwan To Enter Skipjack Tuna Fishery

After remarkable progress in developing tuna longline fisheries, the Republic of Korea (ROK) and Taiwan find they must shift the emphasis of their tuna fishery policy to pole-and-line fishing, according to reports in the Japanese trade press. Both countries now face the problem, often voiced by the Japanese tuna industry, that the subsurface tuna resources in all oceans are being exploited to the limit of their availability and that continued fleet buildup cannot bring about a corresponding increase in catch.

ROK tuna longline landings in 1972 of 83,784 metric tons are reported to be only a slight increase over the 1971 total despite addition of longliners to the fleet in 1971. A number of vessel owners are said to have gone bankrupt as a result.

Thus the ROK and Taiwan are developing plans to enter the pole-and-line skipjack fishery. ROK fishermen are said to have gained much confidence from their government's recent pole-and-line skipjack survey conducted off the Bonin Islands, which resulted in 45 tons of skipjack and albacore landings. Plans reportedly are in progress by the ROK-U.S. joint venture company in Pusan to build a tuna cannery there which would be supplied by a fleet of skipjack vessels. Taiwan is also planning to build 50-ton-class baitboats for skipjack fishing.

Japanese Tell 1972 Joint Fish Ventures

Japan has 77 joint fishery ventures in 38 countries operating a total of 223 vessels, 149 of which are shrimp trawlers, according to the Japan Fishery Agency. Japanese investments in these ventures total $29.1 million ($14.9 million for shrimp and dragnet) while foreign counterpart investments total $43.1 million.

Of the 77 joint ventures, 27 are independent investments by Japan's five largest fishing companies (Taiyo, Nippon Suisan, Nichiro, Kyokuyo, and Nippon Reizo) and 13 involve these five in partnership with trading firms. Some 25 ventures involve smaller fishing companies investing alone or in partnership with trading firms, nine are independent investments by trading firms alone, and three involve other types of investments.

Japanese Firm Tries Culture of U.S. Eels

The experimental culturing of elvers recently imported from North Carolina is being tried by Mochizuki Kinsaku Shoten, a Japanese firm in Yaizu, south of Tokyo.[1] Though the quantity airfreighted to Japan was small—only five kilograms (11 pounds)—the firm is hopeful of achieving success.

The elvers, *Anguilla rostrata*, are reported to be feeding well, but the question is whether they can survive the summer in Japan. If they remain alive until September the venture will have made a successful start.

Successful cultivation of the U.S. elvers will have a large impact on the eel culture industry of Japan. Elver shortage caused by disease and environmental pollution there is also being supplemented with imports from France and other countries. Mochizuki Shoten is the first business firm in Japan to import young eels from the United States. A small quantity of eel fingerlings was first taken to Japan for cultivation in February 1973 by the director of the Eel Culture Research Laboratory in Shizuoka Prefecture who accompanied the Fisheries Agency's Freshwater Fisheries Regional Research Laboratory official to the United States. A second U.S. shipment was scheduled for July.

[1]See "Japan's Eel Fishery" by William B. Folsom, MFR Paper 984, and "Elver Investigations in the Southeast" by Robert Topp and Richard Raulerson, MFR Paper 985, both in the May-June issue of Marine Fisheries Review, Vol. 35 Nos. 5-6.

Quotas, Imports For Fillets, Tuna Given

United States imports of frozen fish fillets, from January to June 2, 1973, amounted to 17,062,700 pounds, the limited quota for that period, while imports of tuna canned in brine amounted to 11,775,666 pounds, according to preliminary data compiled by the Bureau of the Customs, U.S. Department of the Treasury.

Fish fillets that may be imported at 1⅞ cents per pound in calendar year 1973 are limited to a 34,125,403-pound quota. Imports exceeding that quota will be dutiable at 2.5 cents per pound ad valorem. Tuna canned in brine that may be imported at the duty rate of six percent ad valorem in calendar year 1973 has a quota limit of 109,809,104 pounds.

Growth Seen For Brunei Fisheries

The marine fisheries of Brunei (Figure 1) have developed in a relatively short period from traditional fishing

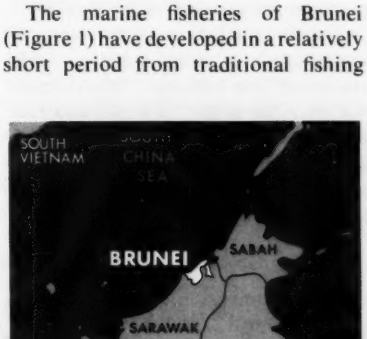

Figure 1.—Brunei, formerly a British protectorate, is situated in northern Borneo between the Malaysian states of Sabah and Sarawak.

to the use of fast boats and modern gear, according to the National Marine Fisheries Service's International Activities Staff. The annual catch has steadily increased to about 2,200 short tons[1] but further significant increase is believed unlikely unless Brunei's fisheries are reorganized and more seaworthy boats, using advanced fishing techniques, are introduced.

A survey carried out by the Brunei Fisheries Department several years ago revealed the existence of fairly rich fish stocks over Brunei's continental shelf. The Department has worked out detailed plans for the development of these resources and a considerable increase in catch can be expected, should these plans be implemented. Orderly fisheries development is possible only with the aid of effective fisheries legislation, such as that passed by the Legislative Council in December 1972.

Brunei's domestic markets were generally well supplied with fish and shrimp during 1972 and the total available in the main markets increased from 1,841 short tons in 1971 to 3,231 tons in 1972. The increase included 450 tons of shrimp and 940 tons of fish. The estimated total catch by Brunei's fishermen alone increased by 569 tons to 2,200 tons.

The market value of all fish and shellfish sold in the three main markets of the country increased by B$2,519,958[2] to a total of B$5,902,989. The consumer price for various grades of fish and shrimp was remarkably stable between 1971 and 1972, varying no more than B$0.02 per kati[3] (less than US$0.003 per pound).

Brunei's Fisheries Department discovered a ready market for freshwater fish when it harvested its ponds and could have sold many times more fish than were available. Also, imported freshwater fish appeared in one of the country's main markets and sold for B$3.00 per kati, considerably more than the average B$1.76 per kati of first grade marine fish. Several businessmen have shown interest in investing in pond culture as a result of the apparent profitability.

[1]One short ton is 2,000 lb.

[2]One Brunei dollar was worth about US$0.35 during 1972.

[3]One kati equals 0.6048 kilograms, or about one and one-third pounds.

Marine Fish Farming Seen Within Decade

Man's dream of being able to farm marine fish as farmers have domesticated and bred cattle and other animals over the centuries is a significant step nearer realization as the result of scientific and technological research and experiments during the past ten years or more, reports the United Nations' Food and Agriculture Organization (FAO).

In this connection an interesting account of the work done in the United Kingdom in "farming" plaice, Dover sole, turbot, lemon sole, cod, saithe and gray mullet is given in a paper to be presented at a forthcoming Technical Conference on Fishery Products. The Conference, which is being convened by the FAO, will be held in Tokyo from 4 to 11 December, 1973, at the invitation of the Government of Japan.

The paper, on Studies on the Acceptability of Farmed Fish, has been prepared by members of the staff of the White Fish Authority, London, the Torry Research Station, Aberdeen, and the Marine Laboratory of the Ministry of Agriculture, Fisheries and Food, United Kingdom.

The experimental farms where most of the work has been done by fish cultivation units are in the Scottish sea lochs at Ardtoe and elsewhere and in the warm outflow from the Hunterston Power Station. In these places Dover sole and plaice have been hatched and reared from egg to marketable size while turbot, lemon sole, cod, saithe and gray mullet have been reared from their juvenile stage after capture at sea to marketable size. Although turbot and lemon sole have also been spawned and hatched they have not yet been reared beyond the early larval stages to metamorphosis in the farms though this has been done in the laboratory.

The teams working on this fish farm program include veterinarians and pathologists looking into problems of health and disease control, nutritionists formulating a variety of wet fish feeds and, lately, moist and dry pelleted feeds, engineers concerned with the design and development of fish holding facilities ashore and at sea, and food science/market development experts who are working with the Torry Research Station staff in assessing the qualities of fish and determining their market and consumer acceptability.

The main effort in all this work is to establish a commercially viable system of fish farming. This includes not only the ability to hatch and rear fish but to produce fish of acceptable appearance, texture and flavor. A series of flavor tests have shown that farm-reared plaice and sole compare reasonably well with the wild fish.

However, tests relating to shape, and skin and flesh colors have indicated some possible consumer resistance. For example, wild plaice have color on their top side and are white on their underside. Farm-reared plaice may vary from no pigmentation on either side to the top-side type of pigmentation on both sides. Such differences, including the darker tinge of the flesh of farm fish, may call for a special marketing effort. But, as the paper concludes "what will determine to a large extent whether farmed fish will be acceptable to the consumer are the method of presentation and the price, both of which could overcome any consumer resistance due to appearance or flavor."

The paper ends on the optimistic note that within the next ten years fish farms "will be producing perfectly acceptable fish on a viable commercial basis" but adds that "the farmed fish of the future may not resemble closely any of the species which are at present on the market any more than domesticated cattle resemble wild cattle or deer."

The paper is one of about 70 to be presented at the Conference. These papers and the discussion will result in a survey for the first time of the world situation of fishery products industry, identifying areas of critical importance at present and likely trends and developments in future.

Publications

Russian Translations

The following three Russian publications were recently translated and printed in Israel for the National Marine Fisheries Service (NMFS), NOAA, under the Special Foreign Currency Science Information Program (financed with Public Law 480 funds). They are sold at the indicated prices by the National Technical Information Service (NTIS), Springfield, Va. 22151. When ordering, cite the translations' accession numbers.

1. "Chemistry and Technology of Pacific Fish," by I. V. Kizevetter, Pacific Research Institute of Marine Fisheries and Oceanography (TINRO), Vladivostok, 1971, 304 pp.

The volume presents a precise chemical and technological characterization of traditional Far Eastern fishes as well as of many commercial species handled by Soviet fisheries in the Pacific Ocean. The species studied encompass the western and eastern areas of the North Pacific including the tropical latitudes of the eastern zone, the Korean Straits, the South China Sea, the Gulf of Tonkin, the eastern part of the Indian Ocean, the coasts of Western Australia and New Zealand, and the Australian Bight.

Accession number: TT 72-50019. $6.00.

2. "Life Activity of Pelagic Communities in the Ocean Tropics Based on Data of the 44th Cruise of R/V *Vityaz*," edited by M. E. Vinogradov, Academy of Sciences of the U.S.S.R., P. P. Shirshov Institute of Oceanology, Moscow, 1971, 298 pp.

A collection of 24 papers dealing with the biological productivity of ocean tropics, specifically of an area of the Pacific Ocean south of the equator and west of 180°E. Topics

covered by the papers include: the process of creation of primary production; evaluation of the utilization of solar energy in a pelagic community; vertical variations of primary production; analysis of the pigment system of phytoplankton and its variability; the abundance and production of the microbial population and its role in zooplankton alimentation; investigation of the specific composition of pelagic communities in tropical waters; tropic structure of plankton communities; determination of the production intensity of zooplankton; quantitative evaluation of metabolic processes in planktonic organisms; evaluation of the part played by fish larvae in pelagic food chains; distribution and composition of organic detritus and its mineralization characteristics; bioluminescence as a manifestation of the life activities of pelagic communities; and studies of hydrological and hydrochemical environmental parameters, including the distribution of nitrogen, phosphorus, silicon, and iron.

Accession number: TT 72-50035. $6.00

3. "Soviet Fisheries Investigations in the Indian Ocean," edited by A. S. Bogdanov, Proceedings of the All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Moscow, 1971, 152 pp.

A collection of 10 papers covering the results of the 2nd VNIRO expedition to the Indian Ocean on board of R/V *Akademik Knipovich* from December 1965 through May 1966. The expedition studied the northern part of the Indian Ocean for determining the possibility of developing Soviet fisheries in that region. Investigations were carried on the shelves of the Bay of Bengal, the eastern part of the Andaman Sea, and, to a lesser extent, areas south of Madras. They included oceanographic research; collection of plankton, benthos, commercial invertebrates, and fishes; industrial fishery techniques; and the technology of products from commercial species. Catches and the ichthyofauna of the surveyed regions are discussed in great detail.

Accession number: TT71-50128. $3.00

Polish Translations

The translation and printing of selected articles from the Polish journal *Technika i Gospodarka Morska* (Marine Technology and Management) was recently started in Poland for the National Science Foundation under the Special Foreign Science Information Program (financed with Public Law 480 funds). The translations are sold for $3.00 per copy by the National Technical Information Service (NTIS), Springfield, Va. 22151. Selections from two or three issues are included under one cover and the first ones to be published are from Vol. 20, 1970: Nos. 1-2 as TT 70-55125/1,2, and Nos. 3-4 as TT 70-55125/3,4. When ordering, cite the translations' accession numbers. Articles on fisheries in the translated issues include: world fisheries in 1968; future of Polish fisheries in the Baltic Sea; activation of the Polish salmon fishery; progress in deep freezing of fish; fisheries and agriculture—comparison of two fields of economy; information service system for Soviet fisheries; results obtained by various types of fishing vessels; role of short-range fisheries; commercial law as an instrument of guidance in the East German fishery economy; Polish marine fisheries in 1969; Polish fishery zone; and assessment of fish quality by means of hydrolocation devices.

German, Italian Translations

One Italian and two German fishery publications produced by the Naples Zoological Station were translated and printed in Israel for the Smithsonian Institution under the Special Foreign Currency Science Information Program (financed with Public Law 480 funds). Their titles and accession numbers are: "Fauna and Flora of the Bay of Naples," Monograph No. 38, Eggs Larvae and Juvenile Stages of Teleostei, by Salvatore Lo Bianco, Parts I and II, 1931-1933, 417 pp., TT 68-50346; and "Fauna and Flora of the Bay of Naples," Monograph No. 35, *Cephalopoda*, by Adolf Naef, Part I, Vol. I, Fascicle I, 292 pp., TT 68-50343/1, and Part I, Vol. I, Fascicle II, 917 pp., TT 68-50343/2. The Smithsonian Institution was unable to obtain the copyright release for these publications. As a result, they were printed in a very limited number of copies and no outside distribution was made. The Naples Zoological Station has recently informed the Translation Program, National Marine Fisheries Service, that it has a small supply of the translations in paper cover and is willing to sell them for $16.00 per copy. They can be ordered from Prof. G. Bacci, Commissario Governatorato, Stazione Zoologica, Naples, Italy.

Recent NMFS Scientific Publication

NOAA Technical Report NMFS SSRF-668, Serchuk, Fredric M., and David W. Frame, **"An annotated bibliography of the cunner** *Tautogolabrus adspersus* **(Walbaum)."** May 1973, ii + 43 p. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

ABSTRACT

This annotated, indexed bibliography of the cunner contains 347 entries including references on taxonomy, distribution, life history, physiology, behavior, commercial and sport fisheries, and related fields. It may be considered current through June 1972.

NMFS Scientific Publications and How to Obtain Them

• The National Marine Fisheries Service Scientific Publications Staff issues three periodicals and five series of publications that appear irregularly.

• The periodicals are *Fishery Bulletin*, *Marine Fisheries Abstracts*, and *Marine Fisheries Review*.

Fishery Bulletin is now in its 71st volume, making it one of the older American scientific publications. After years of appearing irregularly, it became a quarterly in January, 1972. Scientific Editor is Reuben Lasker, physiologist, NMFS Southwest Fisheries Center, La Jolla. Managing Editor is Kiyoshi G. Fukano. The average number contains about 20 scientific papers and is about 250 pages long. *Fishery Bulletin* is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Price: $8.00 a year ($2.00 more for foreign mailing); single issue, $2.25.

Marine Fisheries Abstracts, a monthly, contains abstracts and digests from published articles relevant to all aspects of marine fisheries. Over 700 scientific journals are regularly monitored for material. About 1600 abstracts are printed a year. Editor is Frank T. Piskur, Associate Editor, Samuel Waterman. It is available from the Superintendent of Documents. Price: $6.50 a year ($1.75 more for foreign mailing); single issue, $0.65.

Marine Fisheries Review, a monthly, presents recent developments in the fisheries and fisheries research, with emphasis on the activities of the National Marine Fisheries Service. Editor is Thomas A. Manar. It is available from the Superintendent of Documents. Price, $12.50 a year ($3.25 additional for foreign mailing); single issue, $1.25.

• The series issued irregularly are *NOAA Technical Report NMFS SSRF*, *NOAA Technical Report NMFS CIRC*, *NOAA Technical Memorandum NMFS*, *Data Report*, and *Fishery Facts*.

NOAA Technical Report NMFS SSRF and *NOAA Technical Report NMFS CIRC* are continuations of two previously established series, the *Special Scientific Report—Fisheries* (since 1949, almost 700 numbers have been issued) and the *Circular* (since 1941, almost 400 numbers have been issued). The publications are sold by the Superintendent of Documents. Of varying length, they are individually priced. Their publication is noted in *Marine Fisheries Review* and in *Business Service Checklist*, which is issued by the U.S. Department of Commerce, a weekly publication costing $5.50 a year and available from the U.S. Department of Commerce, FCAT Br., Rm. 6880, Washington DC 20230.

NOAA Technical Memorandum NMFS consists of reports of primarily local interest. They are available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22151. Their publication is noted in *Marine Fisheries Review*, NTIS's *Government Reports Announcement* and *Government Reports Index*. Prices vary according to length.

Data Report is a series that contains oceanographic and biological data. The reports appear in two forms: as microfiche and in hard-copy (full-size). Both are available from NTIS. They are individually priced. Their appearance is noted in *Marine Fisheries Review* and the two NTIS publications mentioned above.

Fishery Facts, a new series, appears irregularly. Each number deals with a single fishery or a single aspect of a fishery. The publications are available from the Superintendent of Documents. Prices vary according to length. Their publication is noted in *Marine Fisheries Review* and *Business Service Checklist*.

• Lists and indexes of these publications have been issued (or shortly will be) covering the years from 1920 to 1972. *Fishery Bulletin* contains an article, title, and subject index in the last (October) number each year. The December number of *Marine Fisheries Review* will carry a similar index. The other series are listed and indexed in: *Fishery Publication Index, 1920-54*, Circular 36, Fish and Wildlife Service, U.S. Department of the Interior, U.S. Government Printing Office, Washington, 1955, and *Fishery Publication Index, 1955-64*, Circular 296, Fish and Wildlife Service, U.S. Department of the Interior, U.S. Government Printing Office, Washington, 1969, and—for the years 1965 through 1972—in a series of *NOAA Technical Report NMFS CIRC*'s issued by the NMFS Scientific Publications Staff, Seattle, Wash.

• Back copies of NMFS scientific publications are often difficult to obtain, for editions are small and often go rapidly out of print. The Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235 is the official distributor of such publications and requests for back copies should be addressed there. T.A.M.

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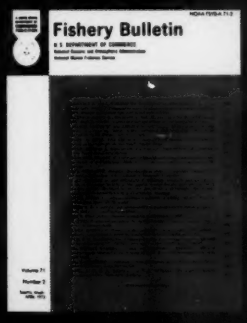
Fishery Bulletin

Issued quarterly under the auspices of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Fishery Bulletin* consistently publishes scientific papers that are in the forefront of fisheries research. The contents of Vol. 71, No. 2, April 1973, reflect its breadth of scope.

Scientific Editor of the *Fishery Bulletin* is Reuben Lasker, physiologist, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California. Subscriptions are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Subscription price: $8.00 per year ($2.00 additional for foreign mailing). Cost per single issue, $2.25.



Scientific advice on catch levels, *J. A. Gulland* **and** *L. K. Boerema,* **Department of Fisheries, FAO, Rome, Italy.**

Comparative study of adaptations for continuous swimming and hydrostatic equilibrium of scombroid and xiphoid fishes, *John J. Magnuson,* **Laboratory of Limnology, Department of Zoology, University of Wisconsin, and Visiting Scientist, Southwest Fisheries Center, National Marine Fisheries Service, NOAA.**

Asymmetry analysis in fishes: A possible statistical indicator of environmental stress, *David W. Valentine,* **Dames and Moore, Los Angeles,** *Michael E. Soulé,* **Department of Biology, University of California at San Diego, La Jolla, and** *Paul Samollow,* **Zoology Department, Oregon State University, Corvallis.**

Distribution of sand lance, *Ammodytes* **sp., larvae on the continental shelf from Cape Cod to Cape Hatteras from** *RV Dolphin* **surveys in 1966,** *Sarah W. Richards,* **Little Harbor Laboratory, Connecticut, and** *Arthur W. Kendall, Jr.,* **Sandy Hook Laboratory, Middle Atlantic Coastal Fisheries Center, National Marine Fisheries Service, NOAA.**

Food and growth parameters of juvenile chinook salmon, *Oncorhynchus tshawytscha,* **in central Columbia River,** *C. Dale Becker,* **Ecosystems Department, Battelle Memorial Institute, Pacific Northwest Laboratories.**

Some aspects of the ecology of lanternfishes (Myctophidae) in the Pacific Ocean near Hawaii, *Thomas A. Clarke,* **Hawaii Institute of Marine Biology and Department of Oceanography, University of Hawaii.**

Cell types, differential cell counts, and blood cell measurements of a Portuguese shark, *Centroscymnus coelolepis,* **captured at 700 fathoms,** *Stuart W. Sherburne,* **Northeast Fisheries Center, National Marine Fisheries Service, NOAA.**

Morphological study of diagnostic characters in western Atlantic *Hepomadus* **(Crustacea, Decapoda, Penaeidae),** *Isabel Perez Farfante,* **Systematics Laboratory, National Marine Fisheries Service, NOAA.**

Helminth parasites of porpoises of the genus *Stenella* **in the eastern tropical Pacific, with descriptions of two new species:** *Mastigonema stenellae* **gen. et sp. n. (Nematoda: Spiruroidea) and** *Zalophotrema pacificum* **sp. n. (Trematoda: Digenea),** *Murray D. Dailey,* **Department of Biology, California State University at Long Beach, and** *William F. Perrin,* **Southwest Fisheries Center, National Marine Fisheries Service, NOAA.**

Vertical distribution patterns of goldeye, *Hiodon alosoides,* **in Fort Peck Reservoir, Montana,** *James L. Cooper,* **U.S. Forest Service, Kaniksu National Forest.**

A meristic and morphometric comparison of the hakes, *Urophycis chuss* **and** *U. tenuis* **(Pisces, Godidae),** *J.A. Musick,* **Virginia Institute of Marine Science.**

Albacore oceanography off Oregon—1970, *William G. Pearcy,* **Department of Oceangraphy, Oregon State University.**

Age and growth of the winter flounder, *Pseudopleuronectes americanus,* **on Georges Bank,** *Fred E. Lux,* **Northeast Fisheries Center, National Marine Fisheries Service, NOAA.**

Problems of bias in models to approximate ocean mortality, maturity, and abundance schedules of salmon from known smolts and returns, *Robert H. Lander,* **Northwest Fisheries Center, National Marine Fisheries Service, NOAA.**

The distribution of summer flounder, *Paralichthys dentatus,* **eggs and larvae on the continental shelf between Cape Cod and Cape Lookout, 1965-66,** *W. G. Smith,* **Middle Atlantic Coastal Fisheries Center, National Marine Fisheries Service, NOAA.**

Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout, *Wesley J. Ebel, Donn L. Park,* **and** *Richard C. Johnsen,* **Northwest Fisheries Center, National Marine Fisheries Service, NOAA.**

Digestive system and feeding habits of the cunner, *Tautogolabrus adspersus,* **a stomachless fish,** *Labbish Ning Chao,* **Virginia Institute of Marine Science.**

The pygmy whitefish, *Prosopium coulteri,* **in western Montana,** *G.F. Weisel,* **Zoology Department, University of Montana, D.A. Hanzel, Montana Fish and Game Department, and R.L. Newell, Department of Biology, Idaho State University.**

Occurrence of mature redfish, *Sebastes marinus,* **in sport fishery of the New York Bight,** *Chester C. Buchanan,* **Atlantic Estuarine Fisheries Center, National Marine Fisheries Service, NOAA.**

Optimum light and temperature requirements for *Gymnodinium spendens,* **a larval fish food organism,** *William H. Thomas Anne N. Dodson, Carol A. Linden,* **Institute of Marine Resources, Scripps Institute of Oceanography, University of California, San Diego.**

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